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Review

I Ke Ēwe ʻĀina o Ke Kupuna: Hawaiian Ancestral Crops in Perspective

Aurora Kagawa-Viviani [1], Penny Levin [2,*], Edward Johnston [3,4], Jeri Ooka [4], Jonathan Baker [4,5], Michael Kantar [6] and Noa Kekuewa Lincoln [6,*]

1 Department of Geography and Environment, University of Hawai'i at Mānoa, Honolulu, HI 96822, USA; kagawa@hawaii.edu
2 E kūpaku ka ʻāina, Wailuku, HI 96793, USA
3 ʻAlia Point ʻAwa Nursery, Pepeʻekeo, HI 96783, USA; aliapoint@gmail.com
4 Association for Hawaiian ʻAwa, Pepeʻekeo, HI 96783, USA; jeri@hawaii.edu (J.O.); jonathan.baker@chaminade.edu (J.B.)
5 Division of Natural Sciences and Mathematics, Chaminade University of Honolulu, Honolulu, HI 96822, USA
6 Department of Tropical Plant and Soil Sciences, University of Hawai'i at Mānoa, Honolulu, HI 96822, USA; mbkantar@hawaii.edu
* Correspondence: pennysfh@hawaii.rr.com (P.L.); nlincoln@hawaii.edu (N.K.L.)

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Abstract: Indigenous crops, tremendously valuable both for food security and cultural survival, are experiencing a resurgence in Hawai'i. These crops have been historically valued by agricultural researchers as genetic resources for breeding, while cultural knowledge, names, stories and practices persisted outside of formal educational and governmental institutions. In recent years, and following conflicts ignited over university research on and patenting of kalo (Hāloa, *Colocasia esculenta*), a wave of restoration activities around indigenous crop diversity, cultivation, and use has occurred through largely grassroots efforts. We situate four crops in Hawaiian cosmologies, review and compare the loss and recovery of names and cultivars, and describe present efforts to restore traditional crop biodiversity focusing on kalo, ʻuala (*Ipomoea batatas*), kō (*Saccharum officinarum*), and ʻawa (*Piper methysticum*). The cases together and particularly the challenges of kalo and ʻawa suggest that explicitly recognizing the sacred role such plants hold in indigenous worldviews, centering the crops' biocultural significance, provides a foundation for better collaboration across multiple communities and institutions who work with these species. Furthermore, a research agenda that pursues a decolonizing approach and draws from more participatory methods can provide a path forward towards mutually beneficial exchange among research, indigenous, and farmer communities. We outline individual and institutional responsibilities relevant to work with indigenous crops and communities and offer this as a step towards reconciliation, understanding, and reciprocity that can ultimately work to create abundance through the restoration of ancestral crop cultivar diversity.

Keywords: cultural revitalization; indigenous knowledge; taro; sweet potato; kava; sugarcane; research ethics; restoration

1. Introduction

Agriculture throughout the world emerged as communities managed and selected wild crop relatives to produce dependable staple food resources. Over time, thousands of crop cultivars were developed, unique to the complex geographies of place and culture, evolving multi-layered, inseparable biocultural relationships between plants and people, woven together through cosmologies and genealogies that name core crop plants as ancestors and gods (e.g., [1–3]). Within this

ethno-biological context, intricate agricultural systems emerged, hefted and slipped into ecological flows and topographical and geological boundaries [4–6]. As people migrated across the world, their accompanying plants and cultural practices both diversified and narrowed dietary choices [7–9]. Within the Pacific, the journeys of core crops such as kalo (taro; *Colocasia esculenta*), ʻuala (sweet potato; *Ipomoea batatas*), maiʻa (banana, *Musa spp*.), ʻawa (kava, *Piper methysticum*), kō (sugarcane, *Saccharum officinarum*), uhi (yam, *Dioscorea alata*), ʻulu (breadfruit, *Artocarpus altilis*) and niu (coconut, *Cocos nucifera*) illuminate connections among culturally related groups.

Commencing in the 15th century, colonial institutions shaped by European epistemologies launched fleets of "discovery" into indigenous territories in part to better understand the world through inventory and inquiry and to identify natural resources for markets at home [10]. Prominent among extracted resources were wild and cultivated plants valued for foods, pharmaceuticals, and spices and resources; indigenous cultivars provided useful new crops or traits to improve existing crop production, which continues to the present day. The collection of indigenous crop cultivars has long played a vital role in their preservation in Hawaiʻi and elsewhere, where they are maintained in ex situ (off-farm) collections, often for the purposes of breeding (e.g., Secretariat of the Pacific Community Centre for Pacific Crops and Trees in Fiji, University of Hawaiʻi College of Tropical Agriculture and Human Resources, UH CTAHR). Yet introductions of these crops to new localities and their use in breeding and "crop improvement" programs has had, in some cases, unforeseen consequences, including contributing to the decline of local indigenous crop cultivar diversity [11] or the rise of traits conferring invasiveness [12].

Furthermore, germplasm collection for breeding and genetic manipulation can be experienced by indigenous communities as an ongoing expression of historical injustice, specifically as theft and assault on community-stewarded resources, giving rise to conflicts among researchers, farmers, and indigenous groups [13–15]. In recent decades, explicit concerns have been raised over bioprospecting and biopiracy of traditional plants and their associated knowledge systems, both in Hawaiʻi and elsewhere. While corporate and institutional appropriation of germplasm and benefits continues, it is also being challenged in several arenas through global treaties and local declarations such as the 1995 Treaty and Related Protocols for a Lifeforms Patent Free Pacific [16], the 2001 International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) [17], and the 2003 Paoakalani Declaration [18]. Specifically, Article 9 of the ITPGRFA (which was an outgrowth of the Convention on Biological Diversity (CBD), and the Nagoya Protocol on Access and Benefit Sharing) outlines farmers' rights, explaining and recognizing the unique contribution of farmers to the conservation and creation of plant types that contribute to local and global food security. While such global treaties present a useful framework, these documents are non-binding, and institutions that outline best practices, such as the United Nations (UN), the UN Educational, Scientific and Cultural Organization (UNESCO), International Union for Conservation of Nature (IUCN), and the CBD lack the power to enforce them. Complicating this issue is that public funds and institutions continue to support patenting/trademarking and research approaches considered inappropriate by many members of indigenous and farming communities; along with a range of perspectives on crops research among scholars, including indigenous scholars.

The history of indigenous knowledge and crop biodiversity exploitation provides a backdrop for this paper which reviews the process of restoring kalo, ʻuala, kō, and ʻawa, four Hawaiian crop plants, to contemporary landscapes and communities across Hawaiʻi. In our restoration efforts and writing, we find the cases fall within a biocultural approach defined by Gavin et al. (2015) as "actions made in the service of sustaining the biophysical and sociocultural components of dynamic, interacting and interdependent social–ecological systems." [19] In describing the cultural significance of the crops, we base our analyses on the kupuna crops themselves (kupuna refers to ancestor or starting point). Furthermore, we draw on Linda Tuhiwai Smith's articulation of 25 "indigenous projects" [20] to illustrate how restoration efforts may align with decolonizing methodologies. Smith [20] proposes such projects as a way to re-indigenize research focused on cultural knowledge and respect indigenous

boundaries. Twenty years after its publication, it also provides a measure for assessing what, if any, changes have occurred between research institutions, indigenous crops, farmers and Hawaiians over time. Of the 25 projects, we focus on *remembering*, *returning*, *revitalizing*, *restoring*, *protecting*, *celebrating*, *sharing*, *connecting* and *envisioning*. We add *resilience* and *abundance* to the framework to capture changing perspectives and approaches. Thus, we operationalize the notion of indigenous projects by reviewing the history of ancestral crop development in Hawai'i, exploring the cultural significance and recent resurgence of four kupuna crops with respect to the 'projects,' and analyzing how the cultural significance of these plants can guide ongoing restoration work both ex situ and in situ (on the land).

We begin by first *remembering*. Our first section provides a brief review of Hawaiian agricultural history and context for the current resurgence. We then share examples of four Hawaiian crop plants: kalo, 'uala, kō, and 'awa by first situating each plant in its Hawaiian context of kinship, relationship, and use. We *remember* specific histories of growth and decline, describe the *return* and *revitalization/regeneration* of names and cultivars themselves through collaborations and the *restoration* of the webs of relationships that accompany these plants, and *celebrate* this restoration (Table 1). We move forward towards resilience and abundance through this re-storying and new planters on the land. In a synthesis of our four cases, we *connect* and compare the cases to each other and lessons from other communities working to restore their biocultural heritage. Finally, we *share* lessons learned as we *envision* future research and agricultural approaches that center biocultural perspectives and employ participatory methods to enable effective collaboration between farmers/indigenous communities and researchers in the work to restore kupuna crops.

In focusing this paper on the need to respect and restore these crops in alignment with cultural values, we pay specific attention to the role of public research institutions in conducting pono (ethical, balanced) decision-making and research and extension initiatives as they intersect with biocultural resources and indigenous and local communities. Our examples bring forward an alternative paradigm of partnership. Thus, we suggest new, specific, and focused frames are needed to guide work on indigenous crops, informed by better understanding where indigenous, farmer, and researcher objectives collide or overlap constructively at the contact zone of indigenous crops research.

2. Background: Ancestral Crops in the Hawaiian Landscape

2.1. Early Hawaiian Agriculture and Crop Trajectories

Polynesians settled in the Hawaiian Islands an estimated 1000 years ago likely from within the Society Islands [21,22] arriving with a group of ~25 plants for food and other uses [23,24] including some that remained essential staples in the Hawaiian diet—kalo, mai'a, niu, 'awa and kō. Evidence suggests 'ulu and 'uala arrived in the islands with later oceanic migrations perhaps around the time of Pa'ao (circa 1300 CE) [25–29] while less is known about the arrival and role of uhi (yam) in early Hawaiian food security. From a limited number of Polynesian founder cultivars, Hawaiians developed an estimated 300-400 varieties of kalo, ~250 'uala, 40 mai'a, 35 'awa and 50 kō, numbers based on recovered germplasm and collected names and accounting for various sources of duplication [30–38]. Just nine cultivar names for uhi and two for niu are recorded by Handy and Pukui [33,39], while 'ulu is represented by only a single Hawaiian cultivar [28]. The primarily vegetative propagation of most these plants implies that Hawaiian cultivars persisting today carry much of the same genetic material as the plants that first arrived in the islands [40].

Archaeological fieldwork and geographic information system (GIS)-based models of the extent and trajectory of traditional agriculture reveal a rich landscape of highly productive farming covering at least 250,000 acres, including immense dryland and wetland agricultural terrace systems at the likely peak of the Hawaiian population in the 1700s [41–43]. These were sustained by diverse Hawaiian soil fertility management strategies [39,44,45] and cultivated according to celestial/seasonal and lunar cycles [46–48]. Water and nutrient flows and topography connected irrigated inland agricultural fields and nearshore fishponds within a cohesive traditional ahupua'a and land tenure system [6,39].

By some estimates, these landscapes supported between 300,000 and 800,000 people [49,50] prior to foreign contact.

Between 1778 and 1900, hundreds of thousands of Hawaiians died from foreign diseases taking with them many of the masterful agriculturalists of their time [50,51]. Wetland taro production declined from ~50,000 acres to ~30,000 acres by the end of the 19th century [41], while expansive dryland field systems were abandoned or became cattle lands [52]. Sugar plantations consumed agricultural lands on each island, securing crop growth through vast amounts of surface and ground water diverted from streams, taro fields and fishpond systems [53–55]. The 1893 overthrow shifted de facto governance of the Hawaiian Kingdom and its lands and people into the hands of American business interests and eventually the United States government [56]. The ensuing changes accelerated the erosion of the traditional Hawaiian land tenure system, making the conversion of agricultural lands and waters seemingly permanent [57–60]. The fight to return water to streams and taro systems has persisted for 150 years [61].

Agricultural systems not supplanted by commercial sugarcane shifted from kalo to rice, from ʻuala to vegetable crops, and from local to distant markets. By 1939, barely 1200 acres remained in wetland taro [62]; commercial acreage has hovered around 400 acres since 1965 [63] (HASS/NASS data 1946–2016). Handy [33,39] reported widespread but declining subsistence ʻuala cultivation during his surveys in the 1930s, and today, the 500 acres of commercial sweet potato production include few if any Hawaiian cultivars [64,65]. Hawaiian bananas' role as a staple starch was almost completely lost, while uhi, niu, and ʻawa remained in the shadows, and the extensive ʻulu agroforests that once banded areas of Maunaloa on Hawaiʻi Island and covered large swaths of the southern coasts of West Maui were reduced to bare remnants [54,66]. Despite 200,000 acres at the peak of sugar [67], native kō cultivars survived almost exclusively in germplasm collections and botanical gardens. Further influencing this once abundant landscape was a demographic shift from predominantly Hawaiian farmers to other ethnic groups descended from plantation laborers. Through the end of WWII, Hawaiʻi maintained its ability to feed itself. Today, 90 percent of food consumed in the Hawaiian Islands is imported [68].

The complex influences that altered Hawaiʻi's endemic ecosystems, Hawaiian society, and its fine-tuned agricultural systems over the last 200 years are well-described [43,69]. Yet through the memories of kupuna (elders) raised in the language and traditions of Hawaiian agriculture, the land that holds onto the remnants of terraces and crop cultivars, and through acts of intentional restoration, ancestral gifts and knowledge endure [70,71].

2.2. A Renaissance of Hawaiian Agricultural Crops

The Hawaiian Renaissance of the 1970s precipitated a movement to reclaim identity, language, navigation skills [72], cultural practices, health, education [73], and resource governance. Struggles over sovereignty, burial grounds [74], military occupation [70], and land and water rights [75] fueled a return to traditional foods through restoration of loʻi (wetland taro fields) [76], loko iʻa (fishponds) [77], and the practice of making poi (the staple Hawaiian food made from cooked kalo), including at the University of Hawaiʻi at Mānoa (UH Mānoa). The era birthed a new generation of taro farmers and students who returned to the land [78–80].

Several decades later, within the context of growing Hawaiian and farmer empowerment, clashes over kalo patenting and genetic manipulation by UH Mānoa researchers opened a wide gap between the institution, Native Hawaiians and farmers while simultaneously fueling a community-based renaissance in traditional Hawaiian agriculture [81], thereby forcing the University to consider the significance of native crops in Hawaiʻi. Thus, kalo has been at the center of conflict and the stimulus of new growth, especially among small-scale commercial and subsistence taro farmers.

We explore this renaissance through four indigenous crop examples that center a biocultural perspective and review key events in each crop's recovery and restoration that provide lessons for all indigenous crop recovery efforts. We begin with kalo given its tremendous significance in Hawaiʻi; it

also provides a perspective on the revival of ʻuala, kō and ʻawa. In each case, the cultural value of these crops extends far beyond their monetized value as market commodities. Each example demonstrates the proliferation of work to restore crop biodiversity, both in collections and on farm, and suggests new directions for inquiry.

3. Nā Kūpuna: Kalo, ʻUala, Kō, and ʻAwa—Four Ancestral Hawaiian Crops

3.1. Kalo–A Return to the Source and the Societal Role of a Staple Food

3.1.1. Guardians on the Land

Kalo (taro, *Colocasia esculenta*) is grown throughout much of the world as a staple starch root crop and a vegetable green and considered one of the oldest cultivated food crops (ca 10,000 cal BP, [82,83]). Molecular evidence indicates *Colocasia esculenta* was domesticated separately in both Asia and the Pacific [84,85] with the highest genetic diversity (DNA) found in India and the highest clonal diversity (cultivars) in Southeast Asia and the Pacific [86]. Predominantly diploid cultivars from this region provide the basis for Hawaiian kalo cultivar diversity [87,88]. This botanical lineage is recognized in some of the most important genealogical chants of the Hawaiian Islands, together with the plant's cultural significance which begins side by side with the birth of man.

There are several cosmological stories, such as the Kumuhonua, Mele a Pākui and the Kumulipo, a more than 2000 line chant, [3,25] that parallels scientific theory in the primordial birthing of the organisms, the creation of the world, the islands, and the birth of Hāloa. In the very first wā (era) of the *Kumulipo*, the distant red Kalo Manauea, a reference to a South Pacific taro, appears as a kiaʻi, a guardian on the land, to the manauea of the sea (a smoky red seaweed) [3,25]. The "dusky black ʻApe" appears in the fourth wā, another important food crop member of the Aroid family to which *Colocasia esculenta* belongs. Here, ʻApe is the kapu (taboo) chiefly progenitor, setting the stage for the birth of Hāloa (the kalo) into Hawaiʻi and a symbolic link to Kahiki (the ancient past; Tahiti) [89].

Hāloa-naka-lau-kapalili, the plant, is born in the 13th wā of the *Kumulipo*, emerging from the burial place of the stillborn child of the gods Wākea and Hoʻohōkūkalani [25]. Hāloa, the man, is born, and the chiefly ancestors from which Hawaiians descend follow; the two (kalo and man) are bound together as brothers through parentage and a profound reciprocal kiaʻi relationship. Each feeds the other; both survive. Out of this cosmology emerges the sacred trust that is the foundation of Hawaiian agriculture and cultural identity. Hawaiian oral traditions and written literature link kalo to the principal gods Kāne and Lono, associated with fresh water and agriculture, and the demi-god, Kānepuaʻa [25,33,90–92]. The plant is food, medicine, dye, feed for nearshore fish, tax payments to the chiefs, and offerings for the gods [25,46,62,93,94]. Kalo is also replete with symbolism. From the structure of the parent corm and side shoots (nā ʻohā) comes the word, ʻohana (family) [95]; from its lineage, hardiness and its waving leaves have come a flag of resistance, especially among taro farmers for the return of water to their steams [96]; the sap of the kalo is referred to as koko (blood) reminding us of the sibling connection [89].

3.1.2. Remembering: Dissonant Histories from Collection and Conservation to Hybrids and Genetic Engineering

In the 1920s, driven by the realization that Hawaiian crop biodiversity and agricultural practices were in rapid decline, Gerritt P. Wilder and E.S. Craighill Handy, Bishop Museum researchers, initiated the first formal taro germplasm collections in Hawaiʻi, including cultivars gathered from the Pacific [62]. The fledgling UH Agricultural Experiment Station received its original kalo collection in the mid-1930s from these two sources and individual taro farmers. The authors of *Bulletin 84: Taro Varieties in Hawaii* (1939) recognized that cross-breeding and new cultivar selections were proceeding without a systematic nomenclature for existing Hawaiian taro varieties [62] and developed a taxonomic key that became the seminal work on Hawaiian taro varietal identification.

Since the 1940s, the University of Hawai'i's experiment stations have maintained kalo collections, primarily for research and breeding programs. An important exception to this is the Moloka'i Research and Demonstration Farm which maintains a primary focus on cultivar conservation and production for taro, serving for the last 40 years as the largest and most important true-type Hawaiian kalo plant material distribution center in the islands for local farmers. In contrast, the University's Harold Lyon Arboretum kalo collection focuses on germplasm storage, conservation, and botanical study.

During the 1950–70s, additional cultivars were brought from the Pacific to Hawai'i (botanical garden accession records), some of which were distributed to the agricultural experiment stations. A common pattern throughout this collection history was that names of origin, an important source of information, were frequently replaced or left unrecorded. Later, breeder-assigned codes further distanced cultivars from their identities (e.g., P1–P20 for 20 cultivars from Palau).

At this junction, two trends appear in the University's taro research. The first is an increased focus on a variety of commercial targets [97,98] by selecting and promoting a limited number of Hawaiian kalo varieties felt to be best-suited for these purposes. This, along with demand for product uniformity (i.e., purple poi), contributed towards further decline in taro diversity in farmers' fields. By 1990, a single variety, Maui Lehua (a farmer-developed cross between two Hawaiian varieties, Lehua maoli and Moi, [29]) was the preferred choice in commercial markets and hence farmers' fields, developing over time the usual pest and disease challenges associated with monocropping [99–101].

Second, researchers responded to declining taro yields and wetland soil health with fertilizer and breeding trials. Initially, these were among Hawaiian varieties, followed by Pacific x Hawaiian and later Southeast Asian x Hawaiian crosses [102–104]. An outbreak of taro leaf blight (*Phytophthora*) in Samoa cemented the UH College of Tropical Agriculture and Human Resources (CTAHR) emphasis on developing disease-resistant taro, first by conventional cross-breeding. Three such taro hybrids were patented [102] causing an uproar in the Hawaiian community over indigenous rights to germplasm. In 2006, after student and community standoffs at the University President's office and Board of Regents meetings, the patents were torn up and released. Hawaiians rejected initial offers to hand the patents over, clarifying that kalo could not be owned, even by them [105]. Work on development of Hawaiian kalo hybrids continues, along with patenting of ornamental taro crosses [106,107].

In Hawai'i, numerous undescribed and poorly-tracked introductions and crosses present a significant challenge to maintaining indigenous crop biodiversity and knowledge of kalo varieties [61]. Similarities between these introductions and Hawaiian cultivars complicate efforts to retain true-type Hawaiian and Pacific kalo collections and to help farmers differentiate among them. A tendency for invasiveness (aggressive runners) in crop cultivar introductions from outside Hawai'i and among new hybrids has become a serious issue for some kalo farmers (Figure 1).

Figure 1. An almost cormless invasive hybrid taro with Lehua maoli-like characteristics (bronzing in youngest leaves; lilac purple base) removed from a wetland taro patch, Hawai'i (**left**) and runners expressed in field trials in the hybrid, Pa'lehua, one of the patented taros (**right**). Photo by P. Levin 2006/2011.

At the same time the patent issue arose, individual researchers at UH Mānoa were already investigating the development of disease resistant taro through genetic engineering. Genes for rice chitinase, wheat oxalate oxidase, and grapevine stilbene synthase were inserted into taro [108–110], a process considered a violation of the sacred relationship between kalo and kanaka. The very thought of changing the being and genetic structure of an ancestor was unacceptable to many Native Hawaiian farmers and cultural practitioners [111,112]. Moreover, taro farmers and Hawaiians only learned of the project by chance through a brief report [113] rather than pre-research consultation. Clearly expressing that genetic modification was an undesirable solution that carried high socio-economic risk, including the potential to jeopardize their livelihoods and way of life, taro farmers requested that the research be ended and the plants destroyed. Proactive recommendations were made for more relevant and useful agroecological research directions [61]. Taro growers also reached out to department chairs and chancellors at the university, and the Taro Task Force submitted a formal letter to UH's President offering to work with the university to develop guidance for future kalo investigations without response.

In the years-long effort to persuade the University administration, which carried into the Hawai'i State Legislature, Native Hawaiians, taro farmers, and their supporters passionately demonstrated and lobbied for the cultural integrity of kalo, as a plant sacred to the Hawaiian people, to be honored and maintained. University responses tended to polarize the issue, characterizing such advocacy as a threat to the intellectual freedom of researchers. Inherent in the conflict was the absence of a more holistic approach to the complex challenges of taro and taro field health. The overt focus on "fixing the plant," a concept embedded in commercial agriculture, ignored farm conditions, kinships between Hawai'i and the Pacific, potential for economic injustice, and evidence from the Pacific of cross-pollination risks in diploid taros [84,87]. The outcome was a legislated 5-year moratorium on genetic engineering, specifically protecting Hawaiian kalo varieties but keeping the door open for all other taros [114]; it did not end the conflict. The physical, financial, emotional and spiritual costs of the research and subsequent University response for many taro growers and Hawaiians has never been fully quantified, and many remain deeply wounded and distrustful of the University of Hawai'i. The University's mission as a land grant institution was called into question for the disenfranchisement of communities it was meant to serve. This history has also been described and analyzed in several publications from outsider [111,115,116] and insider [112] perspectives. The framing of farmer/Hawaiian science, knowledge and rights in opposition to- and of lesser value than- the expertise and intellectual freedom of researchers during such conflicts stands out both as a wall and an opening where transformation in research and a higher standard of research ethics might occur.

3.1.3. Connecting Voices—Turning the Canoe

At the height of these conflicts, the Hawai'i Department of Agriculture was called on to convene stakeholders and develop a research program addressing "taro security and purity" without genetic engineering [114]. The resulting Taro Security and Purity Task Force was formalized by the Hawai'i State Legislature in 2008 to address the many other issues affecting taro farming in the islands [117]. The task force was unique in that, by statute, it was required to consist of no less than 50 percent taro farmers along with representatives from 'Onipa'a Nā Hui Kalo, a respected statewide taro farmers' organization, three state agencies, and the University of Hawai'i.

The task force spent a year researching and meeting with farmers on each island and developed 87 recommendations which were submitted in a report to the 2010 legislature.. The web-accessible Taro Security and Purity Task Force Report provided a template to help the University better align research initiatives with community-identified needs for kalo [61]. Notably, the development of disease-resistant taro cultivars is absent from the recommendations. Instead, the Task Force asked all stakeholders to consider that "the development of new hybrid taros does not resolve the underlying responsibilities we have to take care of the soil," and, it "encourages a focus on improving taro yields, and pest and disease resistance and reduction through the improvement of soil and water conditions and the study

of the preferred conditions of traditional Hawaiian kalo cultivars . . . in the search for the most robust matches between taro varieties, farm practices and locations" (p58) [61]. A major recommendation was to "establish policy to guide and encourage taro research that supports taro farmer needs and concerns." While the report represents taro farmer expertise and experiences and is often used by growers to remind agencies of priority issues and established recommendations, informal exchanges suggest most university researchers are unfamiliar with, or even unaware of, these recommendations.

Ku'i Ka Pōhaku, 'Anapa Ke Ahi o Ka Lewa: From the Right to Make Traditional Foods, a Flame

In 2011, the grassroots Legalize Pa'i 'ai Movement fought for and re-established the legal right to pound kalo into pa'i 'ai (the almost waterless stage before poi) and poi using a traditional board and stone and to sell the product directly to consumers (HRS 321-4.7, [118]). This fed an increased demand for Hawaiian kalo varieties in local exchanges, markets and at taro events and raised the revenues to taro growers 200 percent. It also gained the attention of several of Hawaii's rising chefs [119–121], an important factor in expanding consumer demand and improving farmer incomes for lesser known indigenous crops [122,123]. To meet family demands, board and stone workshops and ku'i clubs (poi-making clubs) have proliferated in the islands. Young commercial growers are now planting a more diverse set of Hawaiian taro varieties for these specialty markets rather than monocropping for larger poi mills (Levin, field obs). At least one ku'i club is growing their own kalo supply in the taro patch with established farmers, potentially creating new farmers in the process. As a reminder of the agency and authority of Hāloa, over the last 10 years, an annual poi pounding event at the state capitol (Ku'i at the Capitol) has drawn thousands of taro farmers, cultural practitioners, and students from across the islands in the simple, yet political, act of making food, in recent years preparing 1,000 pound of poi in a single day.

The strength and breadth of the community-based network that enabled the Pa'i 'ai Movement, cultivar protection, the contesting of water allocation decisions that affected taro farmers, and many other efforts can be traced in part to 'Onipa'a Nā Hui Kalo (and its precursors, the Mauka Lo'i and Kalopa'a O Waiāhole), an organization and an idea that providing hands-on experiences in reclaiming and restoring ancient kalo-growing sites and communing around food together also taught the collective power of community. [124,125] Named in honor of Queen Lili'uokalani whose message to Hawaiians during the era of the Overthrow was to be steadfast ('onipa'a), ONHK became a support network for isolated taro farmers; an information exchange ahupua'a to ahupua'a on planting practices, pest and disease management, markets, water and land rights challenges, food security and family wellbeing. Members and participants record that it "awakened laulima" (cooperation) for thousands of youth and community members. [126] Huli (planting material) exchanges, 'ai pono movements (health centered around traditional Hawaiian foods), education from in the lo'i (wetland taro patches) to school gardens and curriculum in schools, and a significant rise in volunteerism on small-scale taro farms (a modern version of collective agriculture labor traditions) are offshoots of this movement. Today, reflecting on the resilience and abundance that the network embodies, the traditions of Hāloa are alive, and are, as Osorio (2016) writes, increasingly "meaningful and instructive" the more that people are involved in the restorative work of 'āina (land) and growing kalo [127].

3.1.4. *Ola Ka Inoa*: The Importance of Identity and the Power of Restoring Names

Early kalo survey work [30,31,39] suggests Hawaiian agriculturalists developed both highly site-specific varieties and more broadly adapted cultivars. The longest-standing and most recent work in Hawaiian kalo biodiversity has documented almost 2000 kalo names from Hawaiian and English language source materials [29]. Even with Whitney, Bowers and Takahashi's (1939) conservative rule of 50 percent duplication in naming, this may more than double Handy's estimates in kalo cultivar diversity (roughly 300–400) to 800 or more unique varieties; a spectacular example of natural cultivar mutation nurtured by human selection and invention. Kalo names reflect keen observational skills, farmer connections to place, often a delicious sense of humor and affirm the poetic beauty of Hawaiian

language and the world of the kalo farmer. Kalo names based on the color and patterns of fish were frequent, such as the Mana ʻōpelu kalo with its dark flecking and pinkish cast that mimics the iʻa ʻōpelu (mackerel scad; *Decapterus pinnulatus*; Figure 2).

Figure 2. Kalo Mana ʻōpelu and iʻa ʻōpelu (*Decapterus pinnulatus*). P. Levin 2014 (taro) and J. Konanui 2014 (fish).

Accurately identifying Hawaiian kalo cultivars (approx. 60 remain) relies on recognizing morphological characteristics, still the most practical method for varietal recognition. Thirteen Hawaii-based botanical gardens, university research stations and individuals now maintain kalo assemblages in the islands. Over the last two decades, regular collaboration between taro experts and plant managers has improved identification and shifted some collections from solely conservation to interactive education, active propagation and distribution. With that, a larger public is being reintroduced to the cultivars and their names.

Identification guides have been essential to improving botanical collections. They have also been unexpected catalysts in community-based biocultural restoration efforts. The 1939 publication of *Bulletin 84: Taro Varieties in Hawaii* by the Hawaiʻi Agricultural Experiment Station [62] is an example of how such information can ignite a tenacious pursuit of rediscovery, even for backyard growers. This humble book has remained a beacon for novices of Hawaiian crop cultivar diversity for almost 80 years and has stood as a silent challenge to learn more and do better. Building on the original work of *Bulletin 84*, cultural practitioner and kalo and ʻawa expert Jerry Konanui and others worked tirelessly over the last 40 years to expand, refine, and reverify cultivar descriptions. A lack of original names and descriptions for Pacific island varieties introduced to Hawaiʻi, as well as parentage and descriptions for hybrid cultivars persists.

Kalo and ʻawa varieties' identification work has gone hand in hand in Hawaiʻi under the guidance of Konanui. The frequency of site visits to collections and workshops increased exponentially as a response to the challenges to kalo that arose within and outside the University. Between 2005 and 2015, Konanui shared his knowledge with enthusiasm and passion in more than 100 kalo varieties

workshops; average attendance rose from 15 to over 100 people. Demand for kalo varieties and *Bulletin 84* has grown in the process. Farmers and poi-making practitioners, with a focus on local markets, are adding value to their product by sharing what they learn with consumers. Growers are also beginning to experiment and make discerning choices about cultivars for planting based on what the names tell them and where they farm. Thus, the power of kupuna crop names is in the libraries of knowledge they carry. Relearning which cultivars belong where in the landscape expands our food security capacity.

3.1.5. Envisioning: Appropriate Research Directions and Applications of Technology

Refocusing our attention on molecular technologies, we note that phylogenetic and population genetic studies of Hawaiian kalo varieties have lagged behind research on taro in Asia and the Pacific, and current tools are unable to clearly distinguish between individual Hawaiian cultivars within ʻohana groupings or beyond regional relationships in some cases [40,128,129]. Analysis based on ISSR-PCR methods suggest strong connections within the Mana and Manini kalo ʻohana of Hawaiʻi to those elsewhere in the Pacific [129]. The group names appear in the Tahitian, Samoan, and Hawaiian languages and they bear common characteristics, strengthening the argument. Another recent study appears to identify the Hawaiian cultivars as a unique set of plant material relative to the rest of the Asia and the Pacific [130]. It is critical to note, however, that the validity of all such studies requires that source material is properly identified at the start of research and living material is maintained for reverification; this involves the expertise of indigenous crop cultivar specialists and the careful maintenance of cultivars and points to some of the limitations of genomic technologies without such protocols and relationships in place.

An effective and high-demand application of proven technologies is the tissue culture work being done by the Hawaiʻi Rare Plant Micropropagation Lab at UH Harold L. Lyon Arboretum (HRPM Lab). The Lab has collaborated for many years with local kalo experts to provide carefully curated, long-term germplasm storage and backup for living collections of Hawaiian kalo cultivars [40]. Helping to safeguard the future of kupuna crops through tissue culture is an example of culturally acceptable technological applications, especially as this contributes to development and maintenance of disease-free material. Accompanied by good land-management practices, it provides tools for strengthening kalo disease resistance from the ground up without necessitating loss of cultivar integrity.

The current network of collaboration between the HRPM Lab, kalo experts, key botanical gardens, agricultural stations, non-governmental organizations (NGOs) and taro growers demonstrates how listening to farmer needs and kupuna crop voices, along with education, has maintained bridges and made invitations possible from the community that are restoring Hawaiian kalo diversity, improving kalo vigor and farmer economics from multiple directions. Shared among them is a respect for kalo origins, a sense of ʻohana, and clear track records of thoughtful engagement in questions of indigenous crops restoration, local food security and kuleana.

Better understanding of the strengths and limitations of various technologies in the rapidly changing field of molecular biology, appropriate application to study questions, and ethical implications will improve research rigor and outcomes. Research attentive to questions of interest to farmers and indigenous communities may improve engagement and acceptance further. Which taro varieties came first to Hawaiʻi and how they are related to each other and to the rest of the Pacific remains a tantalizing question linked to the oceanic migrations of Hawaiʻi's past. Such inquiry might also be part of a journey towards reconciliation, improved credibility and research vigor for the University provided the canoe is properly prepared for, built, provisioned and manned.

As kin (elder brother) and akua (god) in the Hawaiian cosmology, kalo is as powerfully symbolic and present today for some as it was a millennium ago. As we plant more kalo and align agriculture research with kuleana, so, too, will greater attention to indigenous science and thought, and relationship with Hāloa grow.

3.2. ʻUala—Reclaiming History to Restore Diversity

3.2.1. Celestial and Oceanic Connections

While Hāloa (kalo) plays a central role in Hawaiian cosmology and present-day understanding of food systems and family system [131], ʻuala (sweet potato) plays a central role in traditional food systems for Māori in Aotearoa for whom its celestial whakapapa (genealogy) is common knowledge [132,133]. Although ʻuala holds a less revered position in Hawaiian origin stories, the stories of ʻuala that emerge provide us a view into connections of Hawaiʻi and the rest of Oceania. Through the names of deities and ancestors emerge common associations of ʻuala with Hina and ʻAikanaka, ancestor of Kahaʻi, a famous navigator. In Hāna, Maui, hualani (a reference to an ʻuala) is associated with Hinahanaiakamalama (also known as Hinaaimalama or Lonomuku), whose foot is cut off by her husband ʻAikanaka as she leaps toward the moon [1,134]. Veiled references to ʻuala are found in the *Kumulipo* as the seeds of Makaliʻi, Hina, and Lonomuku, and the food of Hinahanaiakamalama (wā 14) [3,25], and later, Hinaaiakamalama is associated with ʻAikanaka, Hema, Kahaʻi, and Wahieloa (wā 16) [3,25], navigators referenced in other traditions across Oceania [1,48,135]. These names allude to ʻuala's association with celestial bodies, lunar cycles, seasonal planting, and navigation. In yet another epic, following a destructive tsunami of Kahinaʻaimalama and Kahinaliʻi, the priest Kanalu opens his malo and finds kalo, ʻuala, kō, maiʻa and ʻuhi which he plants and prays to grow, spread, and repopulate the land [136].

The presence of sweet potato across Oceania has fueled academic discussion among anthropologists for decades (see [137,138]). Archaeologists now contend sweet potato arrived in Hawaiʻi with a second wave of Polynesian arrivals following the plant's introduction to central Polynesia from the South American continent [29,137,139]. R.C. Green suggests the timing of this as 1000–1100 CE [29], and at present, the earliest ʻuala radiocarbon date in Hawaiʻi is 1290-1430 CE for a charcoal fragment from the leeward Kohala field system [140]. Regardless of the exact timing of arrival, what is known is that ʻuala enabled expansion of cultivation and populations into areas generally too dry for kalo cultivation [140,141].

Cultivation in these drier regions was dependent on the skill of farmers and the will of the gods. Documented prayers associated with ʻuala and dryland farming appeal to natural forms associated with the deities of Kū, Lono, and Kāne, imploring clouds to shade and bring rain and calling Kānepuaʻa to root in the fields (for some examples, see [142]). Thus, the cosmological connections of ʻuala with atmospheric phenomena and celestial bodies (as calendars) reflect not only its dispersal but also serve a practical purpose in seasonally dry environments where it was a major staple. ʻUala planting here was determined by the onset of rains and planters were acutely attentive to the skies. "*Hāʻule ka ua i Kahoaea/ Papakōlea, i hea ʻoe?*" (When it rained at Kahoaea or Papakōlea, both ʻuala growing areas, where were you? [143,144]). Across Hawaiʻi, ʻuala was planted primarily with vegetative slips, and planters would have needed access to living material to establish new fields during windows of opportunity. At the same time, ʻuala yields tubers as early as three months, making it the fastest-maturing of the Hawaiian planter's staple crops. "*He ʻuala ka ʻai hoʻōla koke i ka wī*," sweet potato is the food that quickly ends the famine [143].

3.2.2. Naming and Reclaiming: Ongoing Efforts to Deepen and Expand Our Understanding of ʻUala Diversity

Approximately 300 names have been documented for various ʻuala in the Hawaiian Islands [33,36]. These include an unknown number of synonyms and Hawaiian cultivars that may be extinct or known today only as accession numbers within botanical collections [36]. The most comprehensive published descriptions of identifying traits (English language) are found in The Hawaiian Planter [33], informed by E.S. Craighill Handy's visits by to several communities across the Hawaiian archipelago in the 1930s. Although the 300 names and Handy's survey include a handful of introduced varieties (e.g., 'Okinawa,' 'Pukiki'), the large number suggests high cultivar diversity and local specificity (Figure 3). Regardless,

the disconnect between documented names from Hawaiian language records, varieties grown by Handy's informants (some preserved as pressed specimens in the Bishop Museum Herbarium), and current day living collections presents significant challenges. Handy's herbarium specimens did not retain colors and do not include tuber descriptions important for identification.

Figure 3. Four of an unknown number of extant Hawaiian 'uala cultivars (leaves and tubers): top row (L-R) 'Pala'ai,' "Ele'ele,' and bottom row (L-R) 'Kalia,' 'Piko.' Photos by A. Kagawa-Viviani

Another daunting challenge is understanding the nature of the cultivars that persist today in collections and gardens. Cultivars of living sweet potato collections are easily mixed during bed rotations, requiring collection managers to be particularly attentive to distinguishing traits and labeling. Yet another challenge is understanding how much kahuli (mutation, sporting) has shaped the plants we know today; sports are a natural phenomenon and are well-known and described for both Māori kumara [145] and to a lesser extent for Hawaiian 'uala [33]. In conservation-oriented botanical settings where active farmer-informed selection is not occurring, mutants might be perpetuated over multiple planting cycles, leading to altered traits in key identifiers such as leaf shapes and pigments as well as differences in tuber pigments. On the flip side, breeding efforts through the 1900s [146–149] not only produced numerous hybrids, but may have also contributed to disproportionate preservation of flowering cultivars over non-flowering lineages. The extent and nature of hybrids—both natural (open-pollinated) and intentional (hand-pollinated)—in current 'uala collections remains poorly understood. Finally, the natural plasticity of 'uala traits (variation under different environmental conditions) also presents challenges in comparing 'uala observations made at different locations and times. All of the above- mix-ups, sporting, hybrids, trait plasticity, contribute to the challenge of matching today's living cultivars with older written descriptions, names, and stories.

Molecular tools, utilized for some decades to understand the movements and connectivity of sweet potato across the Pacific [150,151], may aid in the effort to reconnect living plants to herbarium collections, and older documented names and cultural knowledge. Current research efforts focus on the genetic relatedness of preserved 'uala specimens in herbaria and Hawaiian varieties maintained in botanical collections [152]. Similar research in Aotearoa has found that Māori kumara have genetics reflecting hybridization with introduced varieties [133]. Despite this, these kumara are still considered a native food. It remains to be seen whether "traditional" Hawaiian varieties that persist today have distinct genetics or reflect hybridization with introduced varieties, and to what extent this may influence cultural valuation of these crops as spiritual and physical sustenance.

3.2.3. Returning ʻUala Diversity to Diets and Landscapes

Understanding how we moved from high crop diversity to the current situation of only a handful of commercial sweet potato varieties is a complicated tale involving pests, climatic variability, population collapse and migration, and changing land tenure, demographics, dietary preference, and market forces [43]. A quick dive into records from Hawaiʻi's Kingdom and Territorial periods implicates a shift toward commercial production favoring the cultivation of introduced varieties. The 1850 formation of the Royal Hawaiian Agricultural Society was catalyzed by the prospect of exporting produce to the recently acquired American coast of California [153]. In 1857, Kalaupapa was exporting 'uala 'likolehua,' 'apo,' and 'halonaipu' along with introduced varieties 'Iapana' and 'Kaleponi' [154]. By 1916, the US Department of Agriculture (USDA) Hawaii Agricultural Experiment Station system was promoting the distribution of "improved" sweet potato varieties such as 'New Era', 'Kauai/Madera', 'Merced/Jersey Sweet' [155,156]. On Kauaʻi, G.W. Sahr advertised, "*Uniform products demand the highest prices. The county agent can help you market a product that can be depended upon. One of the greatest obstacles in marketing sweet potatoes is the existence of so many different varieties, many of which are of inferior quality. The pink Kauai Madera sweet potato is one of the best varieties to plant. Let the county agent aid you in getting cuttings.*" [157] During this Territorial period, USDA agricultural stations actively hosted the import of and breeding of new varieties including crosses with native varieties which continued at the University of Hawaiʻi [146,147], although activities beyond these thesis projects are not well documented. Although introduced sweet potato varieties were already in cultivation at the turn of the 19th century, distribution of new varieties and hybrids oriented toward commercial production and increasing reliance on markets over home gardens may have accelerated the move away from locally-adapted native cultivars.

Changing the trajectory of over 100 years of history is no small task. Yet distributed efforts are underway to reclaim 'uala as a Hawaiian crop. Restoration efforts in dryland field systems (see Lincoln et al., this issue) have stimulated interest in rain-fed cultivation techniques and crop varieties with varied tolerances to drought and introduced pests (see also [158,159]). Efforts are also underway to increase capacity for citizen and student observers to document their cultivars including those persisting in home gardens that may not be included in botanical collections. Ethnobotanical collections across the Hawaiian Islands have safeguarded several dozen 'uala varieties for decades. Field trials of documented 'uala are being conducted now at University research stations to better characterize them and encourage farmers to plant heirloom varieties with uniquely Hawaiian histories. Many in Hawaiʻi are still only familiar with the purple-fleshed, white-skinned 'Okinawan' varieties or imported moist orange-fleshed 'yams.' It will take effort and education to restore appreciation for the older varieties and their place on dinner tables across Hawaiʻi.

As interest in Hawaiian 'uala grows, it is natural that research interests may focus on creating "better" hybrids to feed the masses. Yet the history of 'uala highlights its value in connecting people and providing medicine [160] and sustenance over long voyages, dry regions, and in the most difficult times. Recognizing this context, we are now challenged to move beyond existing paradigms of crop improvement to consider research agendas centered on 'uala's broad accessibility and local specificity, that foster 'uala as a catalyst for restoring indigenous foods to families across Hawaiʻi. *He 'uala ka 'ai hoʻōla koke i ka wī.*

3.3. Kō—A Knowledge Revival and Changes in Crop Use over Time

3.3.1. Kō in Ancient Hawaiʻi

Prior to European arrival, kō played a significant role in Hawaiian agricultural traditions. Kō is associated with the god Kāne, the first of four primary dieties to come to Hawaiʻi; a variety of kō, "Ele', appears second to the kalo 'Manauea' in the *Kumulipo* creation chant [3,25], and plays a central role in the *Kumuhonua* genealogy that provides the lineage of traditional medical experts [161,162]. This importance of kō in these essential religious sagas is manifested in its extensive use in ceremonial

offerings and medicinal practices. Indigenous horticulturalists distinguished upwards of 50 sugarcane cultivars that differed in their appearance, usage, and environmental tolerance (Figure 4) [163]. Agriculturally, kō could be found growing in most arable habitats: along the banks of lo'i (flooded terraces) with mai'a and other moisture-loving crops, stabilizing the banks and shading the water; in backyard gardens where the canes were meticulously manicured; in extensive rainfed systems forming thick hedges that extended for miles, acting as windbreaks; in young lava flows growing in excavated pits, heavily mulched; in boggy lowlands persisting even on brackish waters; and in other conditions. The cultivation of kō, in many cases, appears to have played a critical role in the cropping system, and the almost excessive cultivation of kō may have been to manage landscape level patterns of moisture and nutrients to better cultivate staple crops such as kalo and 'uala [33,39,164,165].

3.3.2. Remembering: Plantations and Germplasms

The earliest development of the sugarcane industry in Hawai'i beginning in 1836 utilized native kō cultivars. Although the Hawaiian cultivars were developed and selected for use in diversified cropping systems, many still exhibited superior production in monoculture cultivation and were exported to plantations around the world. Starting in 1854 with a Tahitian cultivar, an influx of introduced varieties replaced Hawaiian kō in cultivation and, ultimately, even in backyard and other small-scale plantings. Well-known varieties were given Hawaiian names and adopted into cultural norms.

In the early 1900s, a world-renowned breeding program at the Hawaii Sugar Planters' Association (HSPA) began which produced tens of thousands of new hybrid varieties that displaced both Hawaiian and imported sugarcanes. In the late 1800s, as part of the establishment of its breeding program, HSPA conducted statewide reconnaissance of kō, collecting several hundred accessions along with minimal local ethnographic information (typically only a name). From this effort, about 65 unique cultivars were identified, including both Hawaiian and introduced heirloom varieties. In 1932, a bulletin publication, *The Native Hawaiian Canes*, was released describing, with very little detail, the Hawaiian cultivars [166]. Although HSPA has maintained the collection, it has been neglected, resulting in mislabeling and losses of cultivars. Starting in the 1970s and into the 1990s, multiple ethnobotanical gardens took interest in indigenous Hawaiian crops, leading to the dissemination of the HSPA collection. The gardens each added new canes, often presumed to be Hawaiian varieties, from various private sources.

3.3.3. Revitalizing Knowledge of Kō

In the early 2000s, a volunteer effort began to restore the knowledge systems of Hawaiian kō. With a certain irony, the sugarcane industry simultaneously preserved the physical germplasm while eroding the cultural knowledge regarding it. After initial efforts, it was quickly realized that multiple shortcomings in the germplasms existed: the names attached to the modern collection were often incorrect, there was poor documentation or differentiation between native Hawaiian, introduced heirloom, and early hybrid varieties, and there was no identification process for verifying or identifying a cultivar.

Mahi'ai (native farmers) and *kūpuna* (elders) confirmed that contemporary knowledge of kō was almost non-existent; when talking about native varieties, most described only a "red" and "white" type, with no names or more detailed descriptions. A handful of practitioners with more substantial knowledge were identified, but it became clear that the ethnobotanical gardens were considered the primary source of knowledge. Unfortunately, that knowledge was primarily handed down from HSPA, which was minimal to begin with and severely affected by errors and a lack of concern for the accuracy of the ethnographic information.

The effort to rebuild knowledge of kō over the past 15 years has been an ongoing series of partnerships between research and practice. The first major effort involved detailed morphological documentation. After all, if a cane is not identifiable, it cannot be accurately reconnected to its history. Over a ten-year period, this work served to spark increased interest in the specific sugarcane varieties through discussions with germplasm managers and farmers. The efforts resulted in a botanical key

that is now freely available online along with the cultivar descriptions and pictures [167]. Importantly, this work provides clarity for germplasm management by distinguishing Hawaiian kō from other heirloom varieties and providing a clear identification guide to varieties. Efforts are now underway to verify these findings through genetic assessment of the Hawaiian sugarcane germplasms.

Concurrent efforts to rebuild cultural knowledge of kō included interviews and discussions with practitioners that had knowledge of names, uses, and descriptions, tracing germplasms accession back to their roots, examining herbarium specimens and collection notes, and translating primary sources such as past writings by Hawaiian scholars, recordings of ethnographic interviews conducted in the early 1900s, and the Hawaiian newspapers that published over 58,000 pages of articles between 1834 and 1948. From these sources, thorough historical descriptions of the cane varieties, new names and descriptions of lost varieties, unique uses, growing conditions, and agricultural practices were identified.

Simultaneously, efforts were made to share cultivars to have more material available for propagation, education and use, and to connect growers interested in kō to facilitate knowledge exchange. The entire collection was provided to over 20 private growers, with hundreds of growers receiving multiple or individual cultivars. The ethnographic and botanical research provided a stronger sense of the cultivars, and their usage and significance, which enabled outreach and education, still ongoing. Since 2010, 23 workshops on growing, identifying, and cultural uses of kō have been conducted that have reached some 600 famers and practitioners.

Figure 4. A subset of kō varieties illustrating some of the diversity showing, from left to right, 'Nānahu,' 'Moano,' "Ula,' 'Laukona,' 'Hinahina,' 'Hālāli'i,' 'Pua'ole,' and 'Wai'ōhi'a.' Photo by N. Lincoln.

3.3.4. Kō in the Contemporary Period

The efforts to revive knowledge and use of kō have resulted in enhanced interest and awareness, such as the inclusion of five Hawaiian kō cultivars in Slow Food's Ark of Taste, multiple feature articles chronicling kō diversity [168–170], and vibrant exchanges in social media groups. Significant growth in the cultivation of kō has occurred, with an unquantified, but substantial, increase in backyard farmers and the incorporation of kō into small-scale diversified production. One issue remains in that, unlike most other crops, sugarcane is not easily prepared at the home-scale as it requires, at minimum, a press to extract the juice for use.

The enhanced availability of the ethnographic and agronomic aspects of kō have facilitated emerging industries. Processors and restaurants have incorporated cane juice into products, and the

establishment of multiple rhum agricole (alcohol directly distilled from sugarcane juice rather than molasses or sugar as is the case for most rums) producers has led to increased markets for sugarcane production in Hawai'i. The growth of these industries has occurred as the last sugarcane plantation in the state closed its doors at the end of 2016. This has led to significant cultivation of the heirloom varieties, and it is safe to say that more Hawaiian kō varieties are being grown today than at any time in the last 100 years.

The current challenge is to ensure the continued use of kō in the growing markets, and to ensure that it is done in a proper way. Some producers have latched on to kō cultivars because of the rich history and stories that make for good marketing of products, while others exclusively grow kō because of cultural connections. Despite this, few care about the identity of the source cultivar. Research into the nutritional qualities of pure cane juice, which is high in antioxidants, micronutrients, and has half the glycemic index of processed sugar, clearly indicates that heirloom sugarcane cultivars in general offer greater health benefits, although specific studies examining kō have not yet occurred. Steps have been discussed to form an appropriate group to represent the kō, and, in particular, to safeguard the cultivars from excessive commercial exploitation and ensure appropriate giveback from the economic benefits derived from the cultivars and cultural knowledge regarding kō.

3.4. 'Awa—A Cultural Treasure

3.4.1. Dominance and Fate

'Awa (*Piper methysticum*) is a multi-functional plant in the broad categories of ceremony, medicine, and recreation. Cultivars of 'awa may be restricted for use in a narrow sub-category or may be used in all categories. Prepared as a beverage, nothing else was more commonly drunk other than water and coconuts. Names, traditional uses and practices associated with 'awa in ceremony and medicine are embedded in legends and chants and were recorded by Hawaiian and foreign scholars [34]. Upon first arrival to Hawai'i, the ancient gods of Kāne and Kanaloa set about searching for springs so that they could indulge in 'awa; although the land was dry, Kāne struck the earth with his staff and water gushed forth [171]. 'Awa played many roles, but was dominant in Hawaiian ceremony, being considered the favorite of the gods [172,173]. The act of drinking 'awa was important in maintaining the link with one's 'aumākua (deified ancestors) and 'unihipili (family spirits) [1]. For warriors, farmers and fishermen, it was a tonic to relax the mind and body in everyday use [172,174] and it is this factor that may have contributed to its survival into the 20th century.

Yet Western contact challenged and eroded the strong biocultural relationships developed during Hawai'i's centuries of isolation. By the mid-1820s, Western ideologies and Christianity adopted by Hawaiian ali'i eventually resulted in de facto banning of 'awa production and consumption and churches did much to discourage the use of 'awa [172]. In the early 1900s, Hawaiian 'awa still could be found in great groves within the forested places of the islands abandoned by the collapse of the Hawaiian population in the 1800s. Entrepreneurs were given leases to harvest 'awa on lands under the jurisdiction of the new Territorial Forestry Department [175] contributing to the gradual mining of historic 'awa groves as availability and usage declined. Today alcoholic beverages have largely replaced 'awa as the traditional drink among many Hawaiians [172,176].

3.4.2. Revitalizing 'Awa in Hawai'i: A Grassroots Effort

Due to the decades of decline in production and consumption, Hawaiian 'awa cultivars, and the knowledge associated with them, were in danger of being lost. After seven years of searching remote areas to gather planting material and document heritage 'awa plantings, often with the Hawai'i Biodiversity and Mapping Program, a backyard nursery was started in 1992 which has grown into the Ālia Point 'Awa Nursery (APAN). In 1994, APAN's donation of 'awa plants to a Canoe Club fundraiser in Hilo provided an introduction to Jerry Konanui. A friendship was established and a

partnership developed to restore and enhance the understanding of Hawaiian ‘awa here in our islands and the world.

Our first project was with the Center for International Research in Agricultural Developments, Vanuatu and France, to research and publish a comprehensive study of all known Hawaiian ‘awa cultivars—DNA, kavalactones, and morphology. The data clearly demonstrated that Hawaiian ‘awa cultivars are exceptional [176]. The publication of these data coincided with the desire of the Rural Economic Transitional Assistance-Hawai‘i (RETA-H) program to inspire ‘awa growing in Hawai’i.

The Association for Hawaiian ‘Awa (AHA) was created in 1997 for research, education and preservation of the cultural and medicinal values associated with the ‘awa plant, and as a vehicle through which funding to support conservation and education efforts related to Hawaiian ‘awa could be sought. RETA-H funded a program of AHA-led educational workshops on Hawai’i, Maui, Moloka’i, O’ahu and Kaua’i. AHA also published a quarterly ‘awa newsletter. These years of re-building the historic significance of ‘awa involved the efforts of many individuals from a wide range of ethnic, social, economic and educational backgrounds.

Figure 5. Hawaiian ‘Awa Cultivars: 8 of 13 known cultivars of Hawaiian ‘awa: Top (L to R): Pana‘ewa; Papakea, Kumakua, Nene. Bottom (L to R): Hiwa; Uliuli a opulepule no ho‘i (also known as Hanakapi‘ai); Opihikao; Mahakea. Photos by Ed Johnston.

3.4.3. ‘Awa Growing: Boom and Bust

In 1992, the authors of *Kava, the Pacific Elixir* [177] (p. 96) declared “‘Awa is now a relic of traditional Hawaiian culture—an uncommon but attractive plant that can be found for sale as an ornamental in a few commercial nurseries.” Six years later this was no longer true. By 1998, the unique Hawai‘i cultivars were well characterized and being planted throughout the state (Figure 5). By the

early 2000s, an estimated 200 acres of ‘awa were in the ground, with the largest acreage on Hawai‘i Island. Larger farms were Wainani Farms, Ho‘owaiwai Farm, Hawaiian Pacific Kava Company, Pu‘u‘ala Farm, and Kulana Ki‘i. Most of the smaller farms were in Puna. Pu‘u O Hoku Farm/Ranch was the major grower on Moloka‘i. Most Hawai‘i ‘awa farmers were keenly aware of cultivar names and often devoted sections of their plantings to specific cultivars, a practice rarely done in other Pacific Kava growing regions.

During the decade prior to 2004, kava was becoming very popular worldwide as a dietary supplement. Pharmaceutical companies were buying metric ton quantities of dried kava for extraction from the South Pacific and Hawai‘i growers at prices much higher than the traditional drink market, encouraging early harvesting, sloppy processing and adulteration to meet market demand and grasp the price windfall. During this period, kava dietary supplements became linked with liver injury in some individuals. Health advisories from national agencies such as the US Food and Drug Administration about potential hepatotoxicity associated with kava did not distinguish between supplement and beverage preparations as the source of the problem. The traditional water-based beverage market was thus not only adversely affected by higher cost for product, but it also was tainted by the broad-brush definitions used to warn of possible liver damage [178]. The market crashed worldwide and nearly all Hawai‘i farms closed. Three exceptions, at that time, were smaller farms who primarily produced fresh frozen ‘awa pulp using modern chopping and straining machinery for making the traditional beverage (originally by chewing the root to a fine pulp, mixing with water and straining through the sedge, ahu’awa).

Despite more than a decade of research into the possible causes of liver injury associated with kava, there is still no clear understanding of mechanisms by which hepatotoxicity could occur. During the time since the first cases were reported, kava has continued to be consumed both as a supplement and as a beverage, but new cases of hepatotoxicity have not been reported. The Food and Agriculture Organization of the United Nations (UN FAO) and World Health Organization (WHO), in a review of the safety of traditional and recreational kava beverage consumption, concluded that there are significant gaps in the knowledge about kava’s effects on health, but that “There is little documented evidence of adverse health effects associated with traditional moderate levels of consumption of kava beverage, with only anecdotal reports of general symptoms of lethargy and headaches” [179]. An editorial in the *Journal of the American Medical Association* further noted that: “Historic use shows that kava is safe under the strict control of the rituals of Pacific cultures. The traditional beverage is consumed on a daily basis without apparent adverse effects, and kava cultivars considered as noble ones have a long tradition of safe use” [180]. Noble cultivars are cultivars with history of safe, traditional use. All Hawaiian ‘awa cultivars are considered noble. This is an example of traditional knowledge being right all along. Given that the majority of evidence suggests traditionally prepared ‘awa beverage is safe, AHA has been working with the UN FAO and WHO’s *Codex Alimentarius* to add the Hawaiian cultivars to their safe foods and beverage list. This is an on-going effort, not yet completed.

3.4.4. Envisioning How to Sustain and Increase ‘Awa Growing and Use

Currently in Hawai‘i there is a growing market for quality fresh frozen and dry ‘awa, and the revival of traditional knowledge has supported a market for single strain products using traditional varieties. The release of quality ethnobotanical resources has been essential for grower knowledge. Until recently, the authoritative volume on Hawaiian ‘awa was a 1948 publication *Kava in Hawai‘i* [172]. This collection of information was built upon in 2004 in *Hawaiian ‘Awa: A study in ethnobotany* [174]; and most recently the Association for Hawaiian ‘Awa released its original studies and ‘official’ varietal documentation in the free publication *Hawaiian ‘Awa, Views of an Ethnobotanical Treasure* [34] (online at www.awadevelopment.org).

Hawai‘i must grow more of its own ‘awa cultivars if preservation of these plants is to be successful. Education is critical in understanding the role of ‘awa in Hawaiian history and what important research

is currently occurring with ʻawa beverage in a healthful lifestyle. In the past, much of ʻawa research focused solely on kavalactones—often extracted with solvents producing a fragmented product far from the traditional aqueous beverage so revered across Oceania. The ʻawa beverage is much more than just the concentrated kavalactones found in extracts and pills. Dr. Amanda Martin published a study [181] which revealed high levels of variation in chemical content and cytotoxicity of such commercially available kava products. These findings support the traditional knowledge of ʻawa as a beverage, not a pill. As Martin [182] has said: "It's not necessarily that more is better. What you're looking for is the right amount. And with kava an aqueous solution produces the right amount."

4. Discussion

4.1. Connecting: from Restoring Cultivar Diversity to Restoring Abundance

Several themes emerge from the cases examined. Each plant, regardless of function as staple food, medicine, ceremonial or agronomic resource, embodies a sacred relationship with a key role in Hawaiian society. As Hawaiian populations declined and underwent major societal change in the 1800s, each crop experienced a decline in cultivated area and inventory of native varieties, and those that became market commodities were displaced by introduced varieties. Internationally, the loss of local varieties is among the four factors identified by the FAO as threatening traditional agricultural systems, livelihoods and food security (along with unsustainable models of agriculture, land access pressures, and climate change) [183]. The historical threats to Hawai'i's indigenous crops and sustainability mirror challenges faced by communities around the world.

Despite the decline, a resurgence in interest and revitalization of food and food production systems extends across all four crops, albeit at different stages. Traditional crop cultivar diversity was conserved for decades in ex situ collections for largely research purposes while in situ and ex situ revival and restoration of crop diversity was driven by significant individual and collective community-based efforts external to these institutions. The renewal of crop cultivar uses and values was fed by and feeds cultural revival and involved intensive community and farmer engagement, local entrepreneurship, and strong advocacy at the grassroots level. Each case reminds us that the recent recovery of these ancestral crops emerged out of peoples' desires to restore their relationships with plants, foods, and places.

Table 1 summarizes actions across the four cases as five strategies relevant to the contemporary restoration of Hawai'i's indigenous crops: revitalize and regenerate knowledge of cultivars, return them to the landscape (in situ), protect and steward, restore biocultural relationships and heritage, and resilience and abundance. Each case illustrates how various types of research and collaboration have played a role in the resurgence, from the curation and recovery of living cultivars and archival records to the shift from ex situ conservation settings back into the hands of cultural practitioners and farmers so they can be cultivated in situ. Community stewards, educators, collections managers, agricultural extension agents, families and farmers have all participated in the return of kupuna crops to the landscape through varied pathways. Although not discussed explicitly, in all four cases, the voices of kūpuna through moʻolelo (stories), the sensory experience of taste and smell, and the familial experience of preparing and sharing foods are all important elements of remembering and rekindling interest in such crops.

The expansion and diversification of cultivation evident in the examples of kalo and ʻawa commercial plantings also illustrate how shifting perspectives from global back to local, and reconnection with kupuna crop traditional knowledge, can result in products better aligned with traditional values, practice, and use (e.g., paʻi ʻai; fresh ʻawa root). Such products not only resonate with consumers, but also diversify direct-to-consumer and value-added markets for farmers to choose from, raise farm-gate prices, and restore honor and dignity to the livelihoods of small growers, a strategy that is gaining ground world-wide [122,123,184,185].

Table 1. Strategies supporting biocultural restoration of indigenous crops in Hawai'i and creation of resilience and abundance. Values in the four columns reflect the current state of progress for each crop (5: advanced, 1: in infancy, x: occurring but not assessed).

Strategies [1]	Kalo	'Uala	Kō	'Awa
***Revitalize* and *regenerate* the knowledge base**				
Maintain one or more verified (ex situ) crop collections; cultivate kupuna crop specialists; kuleana	5	2	4	4
Research: archival, oral history/ethnographic; storytelling; naming (participatory; community-driven; academic)	4	2	4	4
Cultivar identification resources	Update in prep		In press, online	Completed
***Return* to the landscape (in situ)**				
Restore traditional agricultural sites and practices (educational, non-governmental organization (NGO), community, 'ohana); awakening laulima	3	1	2	2
Diversify, restore, envision novel markets and products (farmers' cooperatives; chef connections)	3	x	3	4
Subsistence/sustenance plantings: expand area and diversify cultivars (food security and surplus)	3	x	2	3
Commercial plantings: expand area and diversify cultivars	2	x	3	3
(Re)Honor farmer livelihoods and lifestyles and practitioner knowledge	3	x	x	x
Farmer to farmer mentoring	4		2	3
Protect and steward				
Awakening to kuleana, onipa'a; envisioning	4		2	3
Legislation and policy	2		1	2
Pono protocols, relationships and research with tools of modern science	1	x	2	4
***Restore* biocultural heritage**				
Workshops, education, outreach (collections managers trainings; community; growers, K-12 schools; university)	5	2	4	5
Festivals; honoring and celebrating; (re)connecting	5		1	5
Community networks of information and resource exchange/sharing; (re)connecting; cultivating resilience	4	1	3	4
Resilience and abundance				
Climate change and disaster resilience; collections on each island	5	1	5	3
Production meets and exceeds local needs and markets	2	1	2	2
Regenerative agricultural practices support kupuna crops	2	1	2	2
Maintaining ongoing kuleana and laulima; multiplying practitioners	4	1	2	3

[1] The first four subheadings are borrowed from Tuhiwai Smith's (1999) twenty-five indigenous projects [20].

Workshops, celebrations, and festivals create a multiplier effect that increases outreach and awareness. For kalo and 'awa, annual festivals provide opportunities for community members to gather and reconnect as well as exchange knowledge and cultivars. As gathering places, they embrace youth, local communities, farmers, visitors, and the general public as consumers and supporters. Celebration is recognized as a vital regenerative act in many cultures where festivals and agricultural ceremonies persist, including those that call the rain and mark harvests and planting seasons and which are highly refined systems that coordinate agricultural activities with natural cycles (e.g, the Hawaiian makahiki season, the Ngan Bongfai of Northeast Thailand, the royal rites and duties of the ploughing ceremonies of India and Southeast Asia, or the many agricultural rituals of the Ifugao [186,187]). Celebration is also recognized among many indigenous NGO groups as an important element in rekindling people's interest and passion for conserving indigenous crop biodiversity (e.g., Fiesta del Maíz of Mexico and the Indigenous Crop Biodiversity Festival which paralleled the IUCN World Conservation Congress in 2016). Art and the art of growing and preparing food entice, engage, inspire and stretch the boundaries of our senses and view of indigenous crops as merely agricultural products. Farmer-to-farmer mentoring, working one-on-one with collections managers and individual

researchers reclaims expertise back into community and suggests a model for balancing roles and guiding research efforts [188–190].

The enthusiasm surrounding indigenous crops resurgence can, however, generate new problems when steps to avoid old patterns of abuse of indigenous knowledge and resources and people are not made. As the kalo case revealed, the seemingly laudable effort to increase disease resistance and yields through purely technical fixes met with strong opposition (kūʻē; resistance and protest) from members of Hawaiian and farming communities, and conflict escalated through the institutional privileging of intellectual freedom over the multiple concerns voiced by community members. Advancing legislation and proposing policy to protect kalo required exhaustive and committed effort to educate communities and decision-makers. The parallel example of the ʻawa boom and bust highlighted how export-driven commodification ultimately left small growers with fewer market options and how, conversely, sustainable solutions can be found in heeding traditional knowledge and use in the modern context. Both cases illustrate the capacity and power of strong networks to overcome local and international judgements.

As interest and acreage in kō and ʻuala expands, the kalo and ʻawa lessons point to the importance of centering and prioritizing the kinship and stewardship relationships of each plant. These cases remind us that a kuleana to a reciprocal and familial relationship to these plants places us in service to the needs of the plants, i.e., tending to soil health, planting and harvesting at proper times, listening, remembering names and moʻolelo and proper usage, sharing abundance. By giving primacy to this relationship, we suggest ethical, acceptable, and sustainable practices, markets, and research can naturally emerge to restore indigenous crop biodiversity and sustainable food systems. Ultimately, such an approach is respectful and acknowledges not only the generations who developed and diversified these distinctively Hawaiian crops, but also the work of the many farmers and caretakers, storytellers, recorders, and families, Hawaiian or not, who have stewarded and continue to care for these kupuna crops today. Across the five key strategies, awakening to the kuleana of caretaking these crops evolves for some into ʻonipaʻa, a steadfast protection of a treasured resource embedded in cultural identity and a deep commitment to the work of recovery. Maintaining both kuleana and ʻonipaʻa in the long term, as in the example of Jerry Konanui, provides leadership, vision and inspiration that guides the larger network of collaborative efforts. Resilience and abundance are both a perception from within community and an overall goal. For Pacific islands, in particular, ensuring cultivar survival in the face of climate change and increasing hurricane frequency involves establishing collections and propagation projects across multiple islands with multiple partners. The cases also tell us that fulfilling local market needs is still a long way off (e.g., while lands in kalo and ʻuala production have increased, to put them on the table of every family requires thousands of acres of land and water not yet accessible). Kalo farmers are noted for the abundance they share with family and community (food, time, knowledge) that contributes to ʻohana and community wellbeing. This has also transferred to guiding the next generation of young farmers and researchers together—a reflection of both kuleana and envisioning the future.

While our cases highlight steps toward reinvigorating and restoring traditional agriculture across Hawaiʻi, we can look to the Parqe de la Papa in the Peruvian Andes for a model of biocultural heritage restoration where the repatriation of traditional potatoes, agrobiodiversity, and community-led solutions are underpinned by cosmologies of kinship (cosmovisión) [191,192]. The FAO's Globally Important Agricultural Heritage Systems Programme [183] provides a model of more intact biocultural heritage landscapes now threatened in the face of economic globalization that might be adapted and leveraged locally to afford better protections for traditional agricultural systems and the knowledge and lifestyles they support. We also learn from challenges and solutions of Ifugao rice-growing communities in the Philippines as traditional rice varieties enter global markets as commodities in an effort to save the heritage landscape [187,193]. Ficiciyan et al (2018) make a case for the complex set of ecosystem services that traditional crop varieties provide [194] which raises important questions

about the resilience of such biocultural heritage to climatic change [195] and the role of biocultural innovation in generating new possibilities in the context of modern economic forces [196].

4.2. Reframing Kupuna Crops Research—'Auhea Kō Kuleana?

Kuleana is defined by Pukui and Elbert as a "right, privilege, concern, or responsibility," as well as conveying title and authority (e.g., over land) and the liability attached to that [89]. We define kuleana as to be in service, to practice and exercise accountability, commitment to a reciprocal and familial relationship such as that exemplified by the metaphor of Hāloa [58]. Noted cultural practitioner, Sam Kaai described how when kupuna talked about 'āina it meant family, not land, with that same reciprocal relationship bringing the circle back to Hāloa. Kuleana in the context of this paper would mean putting mana (spirit energy of character) [197] into the care of indigenous crops. By contrast with the largely transactional exchanges of modern life, it necessitates a sense of reverence for living beings and the histories that created them. In more straightforward terms, it implies taking seriously the work attached to these plants, including attending to associated complexities and ethics, and to 'āina.

4.2.1. Reflecting on the Lessons of Hāloa

Given broad interest in Hawai'i to return to greater local food production and sustainability, we suggest researchers and institutions must shift from the dominant perspective that indigenous crops are merely "genetic resources." Of note is Governor Ige's promise on the stage of the IUCN 2016 World Conservation Congress to double Hawai'i's capacity to grow food by 2030. To move in this direction, we examine the kalo conflict to identify pathways towards more pono (ethical) research protocols and investigator practices (pono is a core concept in Hawaiian decision-making and action, [198]). However, the restoration of pono (ho'oponopono), a prerequisite for moving forward, requires willingness to acknowledge previous wrongs and make good faith efforts to correct them.

The conflict over patenting and genetic modification of kalo exposed a key underlying issue with indigenous crops research at the University of Hawai'i. The rush toward biotech solutions for kalo and the ensuing struggle revealed vastly different worldviews held by university researchers and members of the taro farming/Hawaiian community which were not considered prior to the formation of the research proposal. For some, the cultural significance of kalo (and other crops) means that many activities are simply kapu (taboo), and that plants, animals and the environment as a whole cannot be owned and should be treated with the utmost care and respect, just as any other member of the family [112]. That local taro growers' concerns also went unheard suggests that researchers continue to see farmers and stakeholders as largely *recipients of* rather than *partners in* the research process or *knowledge keepers* from whom they should seek direction, and thus their perspectives are also not considered in the development of research priorities.

Thus, while we agree academic freedom is an important value for public educational institutions to protect, we contend that deploying this defense in the kalo controversy was a straw man and ultimately a means of shirking institutional responsibility to consult and engage with a diversity of views. We challenge such institutions instead to provide space to discuss the limits of so-called "academic freedom" in the context of their local communities and to address, on a truly open and proactive basis, the hotspots and complexities where ethics, history, culture, and power dynamics meet research agendas, and to consider them holistically in terms of both individual and institutional kuleana.

More immediately, a starting point for restoring trust and laying the groundwork for future collaboration is acknowledgement that there are many ways of knowing. Within the metaphors and poetry of indigenous languages and lifeways often exist astute and practical observations and decision-making logics relevant to contemporary study of agriculture and sustainability [183,199,200].

4.2.2. Acknowledge Different World Views, Objectives, and Time Frames

We suggest that an openness and willingness to listen, hear, and understand different worldviews is necessary to enable deeper empirical insight and also mend historic rifts and wounds. By listen, we

mean to be attentive to, or have heightened perceptiveness towards people and research "subjects," which is enabled by actual care—the kind one provides to family members, hence the indigenous metaphors of kinship. A productive exchange might also acknowledge that the modern researcher is often bound to short timeframes of observation while indigenous/local communities tend to be concerned with both immediate survival and livelihoods as well as much longer (intergenerational) windows of observation and outcomes where empirical insights guide decisions to benefit a broader set of individuals over decades and lifetimes. The cases we describe result from the work and commitments made by various individuals to care for a given crop, reaching far beyond any job description. This extends to other indigenous crops not discussed in this paper ('ulu, mai'a; breadfruit and banana) as well. As the successes of crop recovery efforts in Hawai'i indicate, an effective collaborative relationship among academic researchers and members of indigenous and farmer communities recognizes the value of indigenous kinships and the importance of active stewardship of these. How can meaningful and respectful "hybrid" approaches inform—or transform—agricultural research and practice?

4.2.3. Exercise Individual Accountability

Researchers, whether indigenous or not, come with varying identities such as outsider, insider, ally, and everything in between. They must navigate their roles and, in the case of working with indigenous and local communities, may have minimal experience or guidance on how to do this effectively. In general, the onus to build trust is upon individual university researchers working with indigenous and local communities who must recognize the differential authority they are afforded through titles (PhD, etc.) and affiliation. This often comes with a default assumption that they are "expert" even when community members are the keepers of biocultural knowledge, which raises another important aspect of discussion: the need to recognize and respect different forms and sources of expertise. The kupuna crops in this paper illustrate that tremendous expertise is held by cultural practitioners, farmers and other skilled knowledge holders outside of academic institutions, whose knowledge and experience are all too often marginalized by mainstream cultural norms. These forms of knowing can be fundamentally different than that familiar to the researcher, and the complementarity has the potential to provide mutual benefit if partnerships can be established. It is imperative that researchers, particularly those at large public institutions such as universities, recognize such indigenous or local knowledge and acknowledge its caretakers.

At the same time, members of rural, farmer, and indigenous communities may be hesitant to trust representatives of research enterprises and Western educational systems that have played a role in historic dispossession or marginalization [20,201]. This adds another layer of complexity to exchanges, as researchers are all too often unaware of these histories or are poorly equipped to collaborate effectively and find themselves stepping into existing wounds. Individuals can begin fulfilling their kuleana by learning the history and context of their respective place, and drawing guidance from research protocols and best practices including, for example, the International Society of Ethnobiology International Code of Ethics [202], the University of Otago Pacific Research Protocols [203], the still-developing University of Hawai'i Kūlana Noi'i initiative [204], and the Taro Task Force 2010 Legislative Report [61]. Many resources providing guidance on research ethics exist online (for example, see [205]). Simply investing time in relationships though good faith discussion and scoping early in the process is also critical. Effective collaboration would involve asking and receiving permission, keeping in touch, engaging throughout the process, openly sharing outcomes and returning results in a timely manner, based on core principles of participatory action research [206]. We suggest researchers learn history, read broadly, listen openly (including to silences, an early form of dissent), make time for face-to-face interaction, be humble, and pay attention. Such practices are common in social sciences research; applied here, protocols and kapu accompanying indigenous crops establish kuleana at the beginning of a more informed research scoping process.

In the years since the massive community pushback over the patenting and genetic modification of kalo, few changes have been institutionalized at the University. The advocacy and efforts of Taro

Security and Purity Task Force members did, however, lead to creation of an Indigenous Crops position within CTAHR, but true institutional commitment to change remains to be seen. For example, the publicly articulated CTAHR philosophy on agricultural technologies still states: "We uphold the values of academic freedom and respect the rights of farmers and consumers to decide which technologies are most appropriate." [207] Absent are the specifics of how "respect" is enacted, or explicit acknowledgment of the rights of Hawaiians and other indigenous peoples in maintaining and stewarding ancestral germplasm, and how these translate to University decisions. Depsite the disconnect between UH CTAHR and indigenous perspectives in agriculture, change continues along consumer, farmer, economic and cultural pathways.

4.2.4. Formalize Institutional Support, Policies, and Practices for Improved Accountability and Collaboration

While the development of a taro research policy responsive to farmer needs and concerns remains unfulfilled, the Taro Task Force report [61] provides a template for work better aligned with community-identified needs which can be extended for indigenous crops in general. UH Mānoa is the largest public research institution in Hawai'i and was founded as a land grant college on ceded lands by the Hawai'i Territorial Legislature. Although it historically has had a complex and often contentious relationship with members of the Hawaiian community, in 2002, the University's vision statement included the statement, "Mānoa celebrates its diversity and uniqueness as a Hawaiian place of learning." [208] We interpret this as the institutional recognition that UH is situated within a broader context of Hawaiian history and community. Yet persisting attitudes that traditional knowledge and ethnographic research are less valuable and less rigorous than research utilizing modern technologies continue to privilege academic research over community-held expertise. Our cases illustrate the need for a more egalitarian approach and, indeed, a recent initiative to promote greater researcher responsiveness to community needs and collaboration has begun to advance this discussion on the UH Mānoa campus [204]. We observe such efforts are often initiated outside of the university and championed by individual (and often untenured) faculty, staff, and students sometimes with significant risk of retribution. Recent strategic planning documents including a proposal to improve cultural competency among faculty and staff [209] and the recent appointment of a Native Hawaiian Affairs officer could signal an institutional shift. Historically, however, the operationalization of such recommendations is usually met with institutional resistance and requires pressure [210,211]. Beyond policy, an institutional mission to serve the public good in the context of Hawai'i must allow for discussion and change of course, especially when working with matters concerning indigenous and farming communities and where free, prior, and informed consent [212] has not been obtained before embarking on a project. Helping researchers avoid conflict could involve developing an Institutional Review Board (IRB)—like process for working with indigenous crops that effectively holds researchers accountable for considering implications of their research early in the process. A less top-down approach involves institutional support to train researchers in ethical best practices, such as those described earlier, and increase researcher awareness and understanding of local (see other articles in this issue) and global biocultural diversity and heritage conservation/restoration and biocultural design [183,187,191–193,196]. Such an initiative could facilitate opportunities for collaboration and innovation provided trust is present.

Institutions interested in continuing work with indigenous crops must also explore ways to support staff and researchers committed to longer-term collaborations with indigenous crops or communities since developing relationships necessary for collaboration requires significant time and energy. In addition to the cases presented, we note the work of the Breadfruit Institute (also home to the Global Breadfruit Initiative), whose long-term commitment to protecting and honoring cultivar origins goes beyond conservation to maintaining indigenous knowledge associated with each variety, along with agreements for sharing breadfruit varieties and ensuring benefits from distribution return directly to Pacific nations. The two-year grant, pressure to "publish or perish," and the existing tenure review

process prioritizing these can strongly deter researchers from pursuing rewarding but time-intensive relationships and collaborations required for this work.

4.3. Kanu: Envision, Plant, and Cultivate with Intention

A fitting metaphor for productive collaborative work with kupuna crops is Kimmerer's (2013) description of the Three Sisters of corn, beans, and squash [201]. In this, she describes the mutualism made possible when traditional ecological knowledge (TEK) stewarded by indigenous/local communities and scientific knowledge of the academic research community engage in respectful and productive relationships. The elder sister of corn (TEK) is planted first and is the foundation of life, providing food, medicine, materials, and spiritual health. Beans as the metaphor for curiosity-driven scientific ecological knowledge (SEK) whip tendrils as they stretch and climb, reliant on the corn and unable to stand on its own. The plant's nutrient-acquisitive nature provides nitrogen to the corn, and its searching roots can unearth soil resources and bring them to the surface. Left unchecked, however, its excessive growth can take over the garden and choke out all else. Kimmerer asks, "What would knowledge generation look like if we created a mutualism in which the climbing 'beans' of scientific inquiry are guided by the 'maize' of indigenous principles?" The third sister of squash embodies "the climate of mutual respect, intellectual pluralism and critical thinking in which both knowledges, TEK and SEK can grow." The low, spreading layer of leaves, by cooling the soil and suppressing weeds, fosters conditions necessary to the symbiosis, Ermine's "ethical space of engagement" about which he writes "The ethical space, at the field of convergence for disparate systems, can become a refuge of possibility in cross-cultural relations . . . for the effect of shifting the status quo of an asymmetrical social order to a partnership model between world communities." [213,214]. Yet, Kimmerer observes, "the squash is the slowest to germinate, and when young requires the greatest care." The role of the fourth sister is thus critical. "She's the one who noticed the ways of each species and imagined how they might live together . . . We are the planters, the ones who clear the land, pull the weeds and pick the bugs; we save the seeds over winter and plant them again next spring . . . We too are part of the reciprocity." Kimmerer's metaphor provides us a vision for how various worldviews might work together productively to support restoration of kupuna crops.

If those working with kupuna crops are the fourth sister, they/we must recognize the choices made shape the future of our kupuna crops and have important implications for the trajectories of our institutions, our landscapes, and communities in which we live. Below, we suggest general themes to guide pono decision-making:

(1) *Center kinship relationships, biocultural perspectives*. Moving the formerly marginal kinships associated with these plants toward the center also acknowledges the values and work of those that have been largely ignored in formal (funded) crops work; this can also restore balance to previously asymmetrical relationships of power and authority [20,215]. An indigenous crops research agenda for Hawai'i's current multicultural setting will necessarily be informed by and be responsive to local values, ecosystems, history and priorities of representative communities. Such an approach would not only support the ongoing movement to restore kupuna crops and traditional relationships, but also more effectively serve, engage, and learn from Hawai'i and other Pacific communities. As we grow more kupuna crops, can we also grow more attentive to indigenous science and the ethics of responsibility; to how we cultivate mutualisms in our gardens and our social institutions.

(2) *Cultivate with the tools of decolonizing methodologies and participatory action research*. Many of the ethical codes and best practices we suggest align with decolonizing/indigenous methodologies that support communities reclaiming traditional ways of knowing and existing. Related tools can be found in participatory action research [206,216], which crosses multiple disciplines, similarly centers community concerns, and provides tools to researchers interested in enabling change. Work begins with listening, observing and asking to understand community priorities and interests and may yield novel insights, open doors for partnerships, grow more

indigenous/farmer scientists, and garner greater public support. Farmers working from their own fields, and within the context of the natural environment and the production methodologies they use, are often well positioned to define questions for both pure and applied research [189,190]. Such a return to center might give rise to more thoughtful attention to issues of invasiveness, economies of scale, and resistance/resilience to natural disasters and climate change. Interest in longer-term solutions may emerge such as integrated pest management, better soil management, crop cultivar diversification, fallowing regimes or other more ecologically and culturally informed approaches, as well as innovative infrastructure, market and supply chain models. In this approach, community members are partners in the research process, and, we suggest, can and should be empowered to hold the greatest opportunity possible to shape research directions.

(3) *Cultivate spaces of healthy exchange*. Ho'oponopono is a critical first step in the larger process of forward reaching shifts in policy, research and action. We have observed a need for translators and spaces of safe exchange where hard discussions can be held. Yet these safe spaces must be facilitated to aid in closing historic rifts and wounds between indigenous/farmer communities and academic institutions. Until then, progress will continue to be made through individuals shouldering kuleana to care for indigenous crops, one collaboration at a time.

(4) *Allocate institutional support for culturally important facilities, projects and research*. In Hawai'i, the University's network of agricultural stations is a critical interface for research, extension and growers. In exploring ideas of how the University might "decolonize" existing research agendas, one potential avenue is reframing the purpose and operations of the stations to better steward ancestral crops and associated knowledge systems. The four cases clearly demonstrate that mechanisms exist for this, including expanding support for Hawaiian crop collections that prioritize cultivar conservation and maintenance, distribution of clean and verified propagation material, and leveraging existing agricultural infrastructure to better support community needs around developing farmer skills and food security. Kupuna crops have much to teach us and serve as a model for many key principles in sustainable agriculture.

(5) *Foster innovation.* Just as ancestral agriculturalists traveled vast distances with precious kupuna crops in hand, diversified them, and developed complex agroecosystems with great ingenuity, there is need for creativity and innovation in today's work with kupuna crops. In advocating for this, however, we challenge the common and limited perception of "innovation"—a word largely defined by mainstream values and industrial technologies. We return instead to Kimmerer's fourth sister who innovates in cultivation; those who observe, weed, balance, and select, too, are innovators working through an iterative, responsive, reflective process, not unlike the iterative *inspiration, ideation, and implementation* principles of "design thinking." [217] Biocultural design, at the nexus of biodiversity and heritage, decolonizing methodologies, and whole systems thinking offers a process for creative solutions to emerge in a bottom-up, community-led setting [196]. A key consideration in this process is understanding the roles university researchers, cultural practitioners, and farmers play in helping maintain sustainable cultivation and biodiversity in the field and on the landscape. The fourth sister, the planter- farmers, cultural practitioners, researchers, and individuals in positions of authority, must be attentive and plant with intention.

5. Closing

The history of ancestral Hawaiian crops is complex. At the same time, there has been tremendous renewal of interest in restoring their original cultivar diversity and strong community-driven revival of knowledge, germplasm, production, and traditional practices associated with these kupuna crops. Although individual and institutional actions ignited and exacerbated the kalo conflict, other efforts and partnerships to sustain ex situ collections have been instrumental for the return and revitalization of cultivar diversity of the four kupuna crops examined here. Moving forward, we suggest reconciliation is needed along with more informed and thoughtful protocols for researchers and research institutions engaging in work with Hawaiian crops. We envision institutions and collaborations that are based on

a foundation of respect for plants, culture, and people, that work proactively to protect and steward kupuna crops, and that thoughtfully engage with communities to collectively determine appropriate pathways and the next critical steps forward. From such an approach, meaningful and impactful programs can emerge to strengthen the ongoing restoration of kupuna crops, agricultural landscapes, and Hawai'i's communities. We end on a quote from Osorio and Osorio (2016) [127] (p. 193) outlining how such a vision might be achieved: "We need to tell the old stories and also new stories about ourselves. We need to allow people to discover themselves in the stories that describe how we live responsibly for the 'āina, our ancestors, and 'aumākua. We need to demonstrate . . . the depth and richness of lives that acknowledge the spirit of other living beings and how they are a part of us. And here is the point. It really is not possible to think of a mountain summit, a fishery, a taro garden, an ulu tree, or an entire island as both a being that shares your spirit and as property in the same breath . . . Ultimately, it is about reverence."

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