EVALUATING FISH HATCHERIES AS A TOOL FOR FISH RECRUITMENT IN LOKO IʻA

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I certify that I have read this thesis and that, in my opinion, it is satisfactory in scope and quality as a thesis for the degree of Bachelor of Science in Global Environmental Science.

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ABSTRACT

The restoration of loko iʻa faces significant challenges due to extensive changes in land and water use over the past century. Urbanization, agriculture, and infrastructure development have disrupted the natural flow of freshwater and sediment that these systems depend on. Streams that once fed loko iʻa with clean, continuous water are now often diverted, dammed, or polluted. Meanwhile, coastal development has altered shorelines and estuaries, reduced water quality and increasing sedimentation, which can smother pond habitats and block water exchange. Additionally, the introduction of invasive plant species, runoff from agriculture and roads, and changes in land grading and drainage systems all contribute to a landscape that no longer supports the ecological balance loko iʻa require. Fish hatcheries are a novel solution being considered in restoring fish stocks in loko iʻa across the state. I investigated the economic, social, and cultural factors that go into the implementation of fish hatcheries in loko iʻa . To do this, I analyzed aquaculture policies and studies concerning fish hatcheries done in Hawaii, and interviewed experts in aquaculture and natural resources management, as well as native practitioners to explore how hatcheries can be implemented in accordance with Indigenous Hawaiian values. Those in favor of hatcheries see them as a way to provide immediate stocking to loko iʻa , in addition to boosting wild stocks. However, others point out the cost of hatchery operations and push for prioritizing the restoration of upland systems and water quality to revitalize the natural ahupuaʻa system. Therefore, the view on fish hatcheries is myriad, and it is important to reconcile these views to ensure the best results for hatchery implementation.

Keywords: Loko iʻa , Hatchery, Aquaculture, Ahupuaʻa, fish

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1.0 INTRODUCTION

1.1 THE AHUPUA‘A SYSTEM

The ahupua‘a system was an indigenous Hawaiian land division and resource management method that ensured sustainability and balance within communities. It divided the land into sections along watershed boundaries, stretching from the mountains (mauka) to the sea (makai), allowing access to a variety of resources (Mueller-Dombois, 2007; see Figure 1). Traditional Hawaiian governance ensured that land and water resources were carefully managed through communal cooperation; the ali‘i ‘ai ahupua‘a (chiefs who govern ahupua‘a) ruled each ahupua‘a, and appointed a konohiki (headman or resource manager) to ensure equitable distribution and responsible use of resources, and were assisted by luna (subordinate managers) (Tamimi, 1996; Mueller-Dombois, 2007; Steele, 2015). The ahupua‘a system also facilitated specialized agricultural practices. In the uplands, kalo (taro) was cultivated in lo‘i (irrigated terraces), providing a staple food source in the form of poi (mashed kalo). Further down the slopes, crops such as sweet potatoes, bananas, and breadfruit thrived (Handy et al., 1972). Streams and irrigation channels ensured that water was efficiently distributed, benefiting both crops and aquatic life. In coastal areas, fishing and aquaculture played a crucial role in sustaining the population, demonstrating the adaptability and ingenuity of Hawaiian agricultural and aquacultural practices.

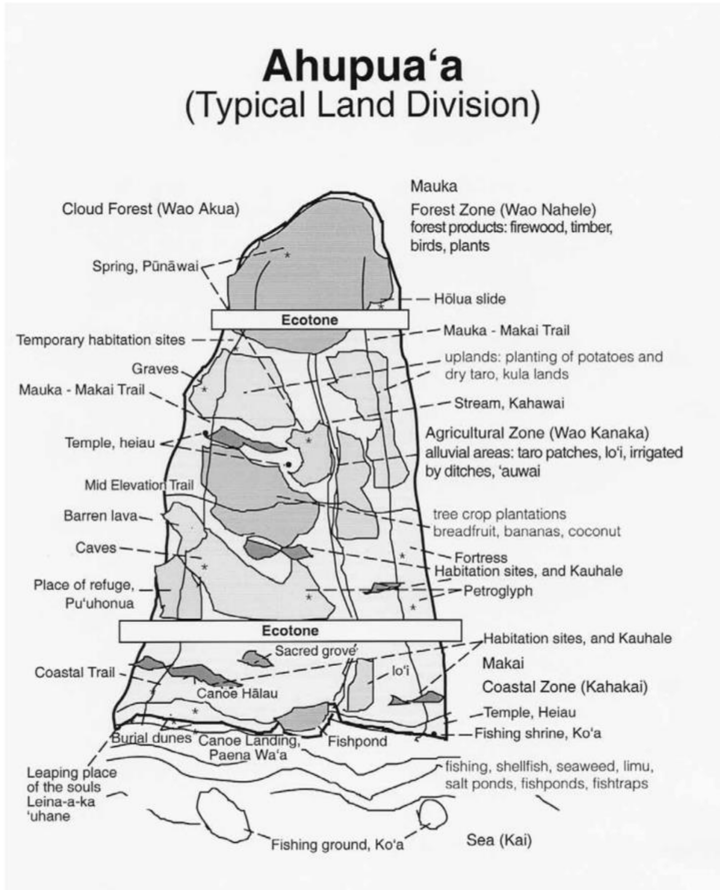

Figure 1: A graph depicting different zones within a typical *ahupua‘a*. *Loko i‘a* are within the coastal zone. From Mueller-Dombois (2007).

1.2 OVERVIEW OF *LOKO I‘A*

Loko i‘a , or traditional Hawaiian fishponds, were an integral part of the ahupua‘a system. These aquaculture structures are known to be dated as far back as 1000-1200 A.D., with development stemming from early fish traps known as loko ‘ume iki (Sato & Lee, 2007). There were different types of loko i‘a , including loko kuapā (walled fishponds), loko pu‘uone (sand-dune ponds), and loko wai (freshwater ponds) (Costa-Pierce, 1987; see Figure 2). Historically, there were around 500 loko i‘a (Bernice Pauahi

Bishop Museum, 1990). Presently, many of these systems are degraded, with around 66 loko iʻa distributed throughout the Hawaiian Islands under restoration, with Hawai'i Island holding the most at 45% (Bernice Pauahi Bishop Museum, 1990; Figure 3).

The general layout for a loko iʻa consists of bodies of water divided by a sluice gate system called mākāhā, which allowed smaller fish to enter the pond while larger fish were trapped inside to grow and reproduce, maintaining a self-sustaining fish population (Sato & Lee, 2007). This was possible due to inputs from freshwater streams and runoff from the mountains, which created a highly productive environment and attracted young fish into the pond (Sato & Lee, 2007).

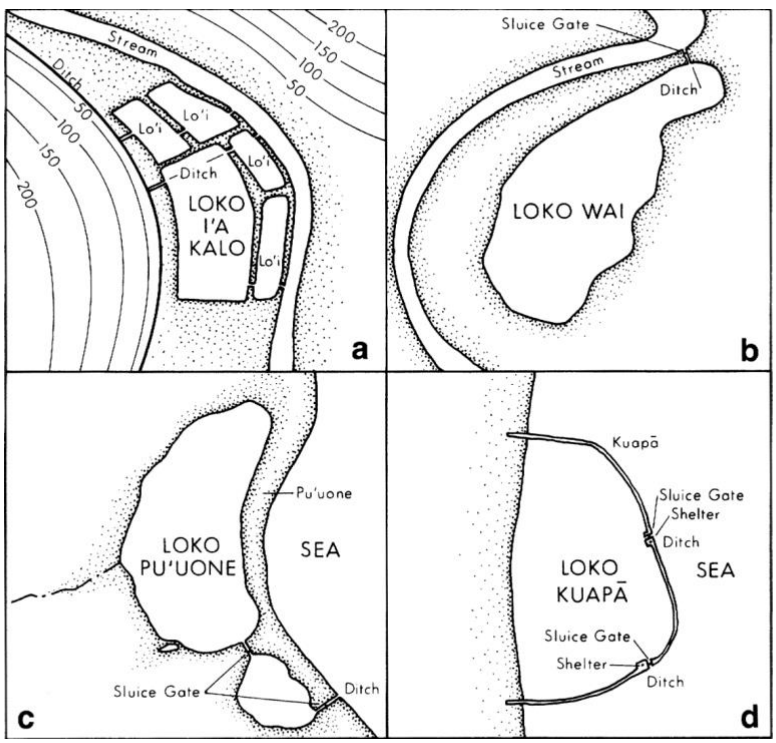

Figure 2: Four types of loko iʻa found across the Hawaiian Islands. From Costa-Pierce (1987).

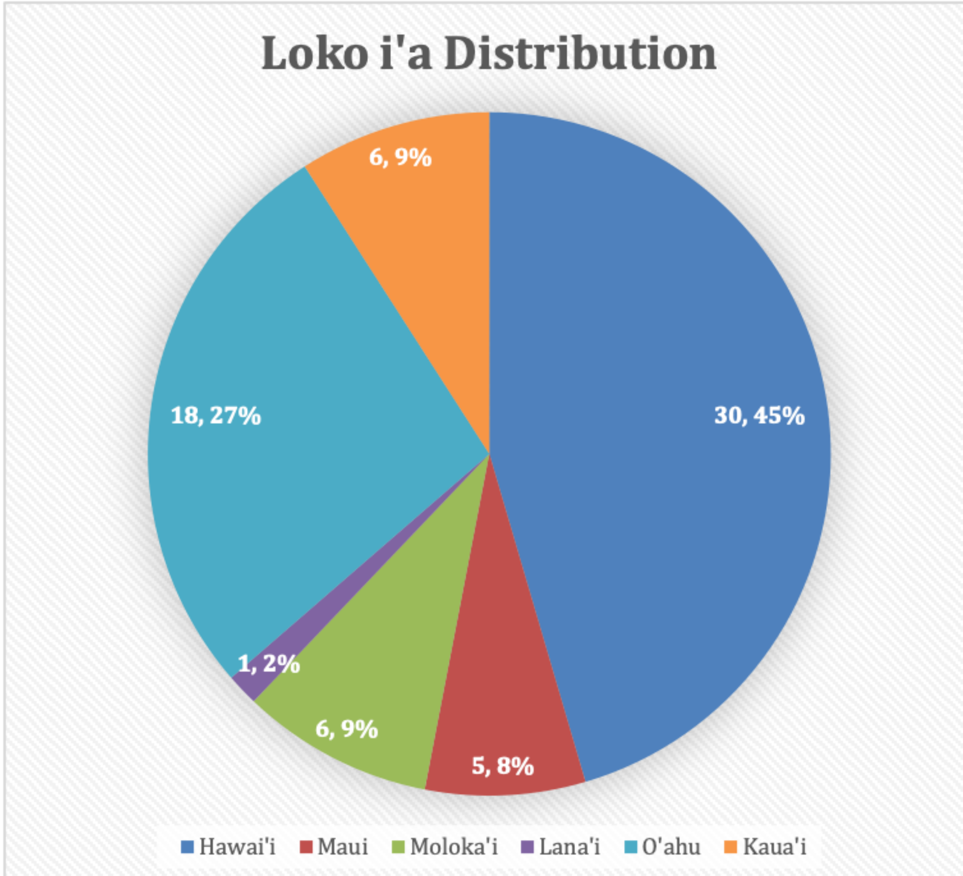

Figure 3: Loko iʻa distribution throughout the Hawaiian Islands. Modified from KUA.

1.3 THE LOKO IʻA ECOSYSTEM

The loko iʻa system functioned as a dynamic ecosystem that supported both marine and terrestrial life. Fishponds were typically enclosed by rock walls with sluice gates (mākāhā) that allowed smaller fish to enter while preventing larger fish from escaping. The nutrient-rich environment within the ponds promoted the growth of phytoplankton and limu (seaweed), which served as a primary food source for herbivorous fish such as awa (milkfish) and ʻamaʻama (mullet), as well as a secondary food source for omnivorous fish like āholehole (Hawaiian flagtail) (Wyban, 2020). These fish, in turn, provided sustenance for the people (Sato & Lee, 2007). While the report will be centered around important fish species within loko iʻa , it is important to highlight that loko iʻa supported a wide variety of species ranging from water birds to invertebrates (Figure 4).

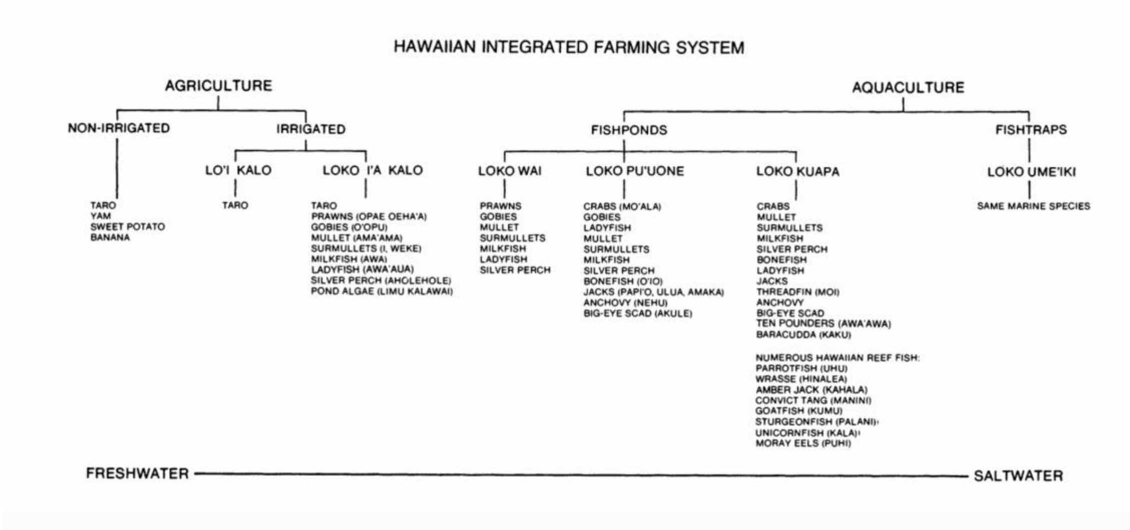

Figure 4: Overview of species cultivated at each loko iʻa system. From Asuncion & Millin (n.d.).

1.3.1 *ʻAMAʻAMA* (*MUGIL CEPHALUS*)

ʻAmaʻama (*M. cephalus*; Striped Mullet) is a catadromous fish found throughout tropical regions of the world, spawning in the sea and inhabiting brackish environments (Wyban, 2020). It is one of two indigenous mullet species in Hawaii, the other being uouoa (*Neomyxus leuciscus*) (Nishimoto et al., 2007). ʻAmaʻama is a popular aquaculture species in places such as Hong Kong, the Philippines, Indonesia, India, Japan, and Israel, and generated the most income for loko iʻa in operation, although in the continental U.S. it is regarded as a trash fish (Wyban, 2020, Sato & Lee, 2007). ʻAmaʻama is categorized based on its stage of growth: pua‘ama for fingerlings, kahaha at hand length, ‘ama‘ama at 8 inches, and ‘anae at 12 inches or more. In addition, its diet changes with growth; emerging larvae primarily feed on zooplankton, shifting to an omnivorous diet and ultimately become herbivorous at a mature stage, feeding on algae and diatoms (Wyban, 2020). The spawning time for ‘ama‘ama occurs in the winter time, ranging from December to March; a kapu, which are a system of laws and regulations in ancient Hawaii, placed fishing restrictions throughout its duration (Nishimoto et al., 2007; Sato & Lee, 2007).

1.3.2 *ĀHOLOHOLE* (*KUHILA SANDVICENSIS*)

Ā*holeho*le (*K. sandvicensis*; Hawaiian Flagtail) is a fish commonly found in both salt and fresh water (Titcomb, 1972). The young and adult fish inhabit different environments; the young swim along sandy, shallow beaches, while the adults stay in reefs, either in lava caverns or the coral (Titcomb, 1972). Additionally, adults are nocturnal, and inhabit deeper depths (Wyban, 2020). Unlike ‘ama‘ama, āholehole reproduce year-round in the wild and could adapt to different types of food, although insects and algae were preferred (Wyban, 2020). Culturally, āholehole were used in ceremonies to ward off evil spirits; they were placed under house posts during its construction, and were used as a substitute for pigs if they were not available (Titcomb, 1972; Wyban, 2020).

1.3.3 MOI (*POLYDACTYLUS SEXFILIS*)

The moi (*Polydactylus sexfilis*; Pacific Threadfin) is a fish belonging to the *Polynemid* family (Callan, Laidley et al., 2012). This species is found throughout the Indo-Pacific, but is the only species of the *Polynemid* family to be found in Hawaiian waters (Chambers et al., 2001). Moi reside in places with high turbidity, and are usually found along rocky shores high energy surf zones, stream mouths, and mangrove estuaries (Callan et al., 2012; Friedlander & Ziemann, 2003). Unlike ʻamaʻama and āholehole, moi were primarily carnivorous, feeding on small fish and crustaceans on the seafloor (Callan, Laidley et al., 2012). Historically, moi were only eaten by chiefs, and were seen as a bad omen when large schools were spotted (Titcomb, 1972; Wyban, 2020). In post-Western contact times, moi has been overfished due to its prized role as food and sport, in addition to facing competition from kanda (*Valamugil engeli*), and efforts have been made to culture the fish for stock enhancement and aquaculture (Callan et al., 2012; Kam et al., 2002; Sato & Lee, 2007). It has also been cultured in round tanks and open-ocean cages in recent times (Callan et al., 2012).

1.4 HISTORY OF FISH HATCHERIES IN HAWAII

Fish hatcheries in Hawai'i first began in the 1950s, when outside marine and freshwater species were introduced with the purpose of fisheries enhancement and aquaculture; these fish included grass carp, common carp, catfish, and ornamentals such as koi (Haws & Seale, 2019). In 1959, the Keehi Bait Station (now known as Ānuenue Fisheries Research Center (AFRC)) was built for the production of baitfish such as tilapia (Haws & Seale, 2019). Throughout the 1960s and 1970s, the AFRC developed culture methods for *Macrobrachium rosenbergii* (Malaysian Prawn). In addition, the Oceanic

Institute (OI) researched into closing the life cycle of ʻamaʻama as well as the development of sea cages for open-ocean aquaculture, which facilitated the production of *moi* as a commercial fish in 1999 (Haws & Seale, 2019). Furthermore, Hawaii's unique quality of housing every known terrestrial climate (barring tundra) allowed for aquaculture developments in fresh, brackish, and salt water (Haws & Seale, 2019).

Other aquaculture facilities include Hawaiʻi Ocean Science and Technology (HOST) Park located at Hawaii Island, which leases space to roughly 20 aquaculture companies as of 2019. Companies with leases in the park commercially raises microalgae, abalone, marine fish, bivalves, seaweed, ornamental fish, seahorses and octopi (Haws & Seale, 2019). In addition to commercial production, many aquaculture tenants at HOST Park also participate in research, with the park growing over the years since 1970 (Haws & Seale, 2019). Aquaculture facilities within Hawaii also work closely with facilities in the U.S. Affiliated Pacific Islands (USAPI), which include the Commonwealth of the Northern Marianas Islands (CNMI), the freely associated nations of the Republic of the Marshall Islands, Federated States of Micronesia (FSM), the territories of American Samoa and Guam, and the Republic of Palau (Haws & Seale, 2019). Notable facilities in USAPI include Marine and Environmental Research Institute of Pohnpei (MERIP) in FSM and the Palau Mariculture Development Center (PMDC). Both facilities are supported by the Center for Tropical and Subtropical Aquaculture (CTSA), and work in the development of species such as giant clams, rabbitfish, corals, and sponges (Haws & Seale, 2019).

2.0 METHODS

2.1 LITERATURE REVIEW

A comprehensive literature review was conducted to gather relevant information on traditional Hawaiian fishponds (loko iʻa), hatcheries, fish recruitment, and the broader concept of ahupuaʻa resource management. The review focused on historical, ecological, and cultural perspectives to provide a well-rounded understanding of these systems. The primary sources for the literature review included: University of Hawaiʻi at Mānoa (UHM) Library, where academic books, theses, peer-reviewed journal articles were accessed through the university's online and physical collections, Google Scholar, where a broad search for scholarly articles, reports, and case studies related to loko iʻa , hatcheries, and fish recruitment was conducted using Google Scholar to supplement university library resources. Key search terms included "loko iʻa ," "hatcheries," "fish," "ahupuaʻa," "recruitment," and related variations. These terms were used individually and in combination to refine searches and ensure a comprehensive review of available literature.

2.2 IRB CERTIFICATION

To ensure the ethical conduct of this research, particularly the protection of participants involved in interviews, this study obtained approval from the Institutional Review Board (IRB) at UHM through the Social and Behavioral Sciences (SBS) IRB. All participants were provided with informed consent forms outlining the purpose of the research, the voluntary nature of participation, potential risks and benefits, and data confidentiality procedures. Interviews were only conducted after receiving verbal and/or written consent from each participant. All collected data were anonymized, securely stored, and used exclusively for academic purposes. IRB certification and ethical clearance were essential to maintaining research integrity and safeguarding participant rights throughout the study.

2.3 SELECTING INTERVIEWEES

Five participants were contacted via email, all of whom subject matter experts in aquaculture, natural resource management, and/or experience in managing loko iʻa ; their occupation and location were noted (Table 1). Prior to the interview, participants were required to sign an IRB consent form detailing the subject and procedure of the interview (Appendix 6).

Table 1: Interviewees and Their Occupation and Work Location.

Interviewee	Occupation	Location
Brandi Lai (BL)	Coordinator for Cultural Restoration Networks	Work across the state
Chad Cullen (CC)	Finfish Researcher	Hilo
Diana Holt (DH)	Coordinator for a High School Marine Science Program	ʻEwa
David Snow (DS)	Manager for an Estuarine Reserve, Faculty Position at a College	Honolulu, Kāneʻohe
Kevin Kohl (KK)	Director for a Loko iʻa Restoration Organization	Kāneʻohe

2.4 CONDUCTING INTERVIEWS

Participants were invited to a Zoom meeting by email. The format of the interview was online, lasting 30-45 minutes with experts being asked 7-8 questions regarding their opinion on fish hatcheries as a viable solution for juvenile recruitment. Additionally, the interviews were audio-recorded; as there is no option for audio only, the video recordings were deleted as soon as they were processed. After the interview, participants were emailed their audio recording, as well as a typed transcript 1-2 weeks later in addition to a $5 Cookie Corner gift card as compensation for their time. The transcripts were then analyzed and further de-identified. Furthermore, participants also received a copy of the thesis after completion.

2.5 ANALYZING INTERVIEWS

Interviews were analyzed by thematic analysis. The interview questions were categorized into 5 distinct themes: traditional knowledge, which concerns the use and integration of traditional knowledge in hatcheries; community engagement, which discusses the relationships between loko iʻa and fisheries and the outside community; policy or governance, which talks about laws and policies which affect hatcheries and loko iʻa restoration; hatchery development, which discusses funding and hatchery operations; and restoration strategies, which concerns alternative methods of restoring pre-contact fish recruitment (Table 2). Answers were analyzed similarly, in addition to counting the number of occurrences of answers between different interviewees.

Table 2: Example Questions and Their Theme.

Question	**Theme**
How do you think modern hatchery practices can be harmonized with traditional Hawaiian methods of fishpond management?	Traditional Knowledge
How important is community involvement in the process of integrating hatcheries into loko iʻa management? What steps have been (or will be) taken to ensure local stakeholders are engaged?	Community Engagement
Are you aware of any policies or regulations that currently govern the use of loko iʻa development or fish recruitment? Are there any changes you believe should be made?	Policy or Governance
Are there any concerns about genetic diversity or the health of fish populations when using hatcheries in these traditional systems?	Hatchery Development
Are there any alternate priorities that we should account for when it comes to fish recruitment?	Restoration Strategies

3.0 RESULTS AND DISCUSSION

3.1 COMMUNITY ENGAGEMENT

Three out of the five interviewees highlighted the open relationships between loko i‘a and fisheries, the challenges of outreach, and the importance of using community networks (Table 3). Fisheries research centers primarily serve an advisory role. For example, Holt (2024) noted that these centers contribute by donating fish of various species and providing expertise when problems arise. Similarly, Kohl (2025) described how Oceanic Institute (OI) shared information about the conditions under which the pua (juvenile fish) were raised before release, but largely left it up to the fishponds to manage their survivability. Cullen (2024) emphasized that fishpond practitioners had actively approached OI to initiate fish production collaborations.

These relationships are exemplified by loko i‘a such as He‘eia and Waikalua, which maintain strong connections with research centers like the Aquaculture and Fisheries Research Center (AFRC) and OI (Kohl, 2025). Lai (2024) further discussed the openness of these partnerships, noting shared concerns between loko i‘a practitioners and fisheries managers about the long-term ecological effects of using hatchery-raised fish.

In terms of outreach, Cullen (2024) explained that engagement efforts currently rely on existing fishpond networks, as hatchery initiatives are limited to a few locations. However, there are plans to expand outreach through state agencies and organizations like Kua‘āina Ulu ‘Auamo (KUA). Holt (2024) also discussed working with KUA to distribute fish to interested organizations. Lai (2024) pointed out that there is a general lack of public understanding about hatchery operations, particularly regarding biosecurity measures. She emphasized the need for greater community engagement to convey this information. Snow (2025) addressed outreach on a broader scale, stressing that not enough communities in Hawaiʻi feel a strong sense of kuleana (responsibility) for the land they inhabit.

Only one interviewee specifically addressed educational programming. Holt (2024) described initiatives such as involving local students through the Marine Science Learning Center at Waiʻa nae High School, where hatchery-related skills are integrated into the curriculum. He also highlighted educational programs at Heʻeia and Loko Ea, which aim to raise awareness about the ecological importance of loko iʻa . These programs are flexible in content based on teachers' learning objectives and serve as a source of income for the facilities. However, they also offer fee waivers or discounts for schools with limited funding.

Table 3: Community Engagement

Answers	# of Interviewees	Interviewees
Open relationship with fisheries	3	BL, CC, KK
Outreach as an issue	3	BL, CC, DS
Utilizing networks	3	BL, CC, DH
Educational programs	2	DH

3.2 TRADITIONAL KNOWLEDGE

Interviewees' views on hatcheries vary between different loko iʻa across the islands. Three out of the five interviewees generally argued that hatcheries would provide fingerlings that would've otherwise been recruited into the ponds, in addition to providing wild stock enhancement outside of loko iʻa (Lai, 2024; Cullen, 2024; Kohl, 2025; Table 4). On the other hand, 2 out of the 5 interviewees talked about how some caretakers of loko iʻa argued that restoration of habitat would bring back the natural cycle of recruitment, with hatcheries being viewed as a temporary solution (Snow, 2025; Lai, 2024; Table 4).

Additionally, three out of the five interviewees highlighted the importance of preserving cultural practices (Table 4). Lai (2024) discussed the point of adapting to changing conditions, such as how traditional cultural values would be perpetuated as hatcheries and other contemporary solutions are put in use. In particular, Holt (2024) talked the use of kilo (observing the environment around you through all five senses), and highlighted that human observation is just as important as collected data, allowing for a full picture of events occurring in that area. Additionally, Snow (2025) talked having small- and large-scale fisheries aligning with values of ʻāina momona (fertile land), and about the use of education as a way to teach from an Indigenous mindset, with the goal of bridging the gap between policy-making and traditional knowledge.

Table 4: Traditional Knowledge

Answers	**# of Interviewees**	**Interviewees**
Support for natural recruitment	3	BL, DS, KK
Preserving cultural practices	3	BL, DH, DS
Temporary solution	2	BL, DS

3.3 HATCHERY DEVELOPMENT

Two out of five of the interviewees talked about funding from legislative sources and lower-trophic species cultivation (Table 5). The Department of Aquatic Resources (DAR) and other agencies are the primary source of funding for hatchery operations

(Holt, 2024; Cullen, 2024). Cullen (2024) indicated that hatcheries are not financially self-sustaining and typically require government subsidies, but suggested that their long-term ecological benefits could justify the costs. Additionally, Holt (2024) discussed funding challenges for establishing a hatchery at her high school, citing high infrastructure costs and the need for consistent financial backing.

With species selection, Cullen (2024) outlined key considerations for species selection, noting that herbivorous species such as mullet are preferable for loko iʻa due to their ability to sustain themselves on natural productivity; their food chain efficiency and protein yield is greater compared to carnivorous species like moi, which would require supplementary feeding (Kikiloi, 2003; Figure 5). Holt (2024) emphasized the economic and logistical advantages of prioritizing mullet, and identified the higher dissolved oxygen demand of moi as a challenge, making them less feasible for remote or grid power-vulnerable locations.

One out of the five interviewees talked about hatchery-reared ʻamaʻama being produced using wild brood stock (Table 5). Cullen (2024) noted that he has not observed any noticeable differences between wild ʻamaʻama and those that are hatchery-reared, as they are genetically identical. In addition, Cullen (2024) acknowledged the importance of genetic markers to prevent negative impacts on wild stocks (Table 5). As of the current interview process, there is an ongoing project supported by the state that aims to collect samples of ʻamaʻama across the island to develop a potential genetic marker to distinguish between hatchery and wild populations (Cullen, 2024). Furthermore, Holt (2024) raised questions about introducing hatchery-reared fish from distant sources, emphasizing the need for location-specific brood stock to maintain ecological integrity.

Additionally, one of the five interviewees discussed the challenges of raising hatchery fish in pond conditions (Table 5). Kohl (2025) stated different environmental conditions that affected pua ʻama survivability exist. On Molokaʻi, Keawanui faced problems regarding predation by both barracuda and ʻaukuʻu (black-crowned night heron); Kohl (2025) additionally noted that the pond was built in a shallow, freshwater environment, which contributed to increased predation. Heʻeia and Waikalua fishponds mainly face problems regarding sedimentation, which affected the oxygen content of the pond especially when the winds become variable (Kohl, 2025). Hale o lono on the Big Island was stated to be the most successful among the loko iʻa that recieved OI-raised ʻamaʻama; the pond had diatoms growing on rocks and sediment, there was no chance for predators to get into the pond, and they were acclimated to a low-salinity environment (Kohl, 2025). However, a king tide broke part of the pua pond and the fish escaped (Kohl, 2025).

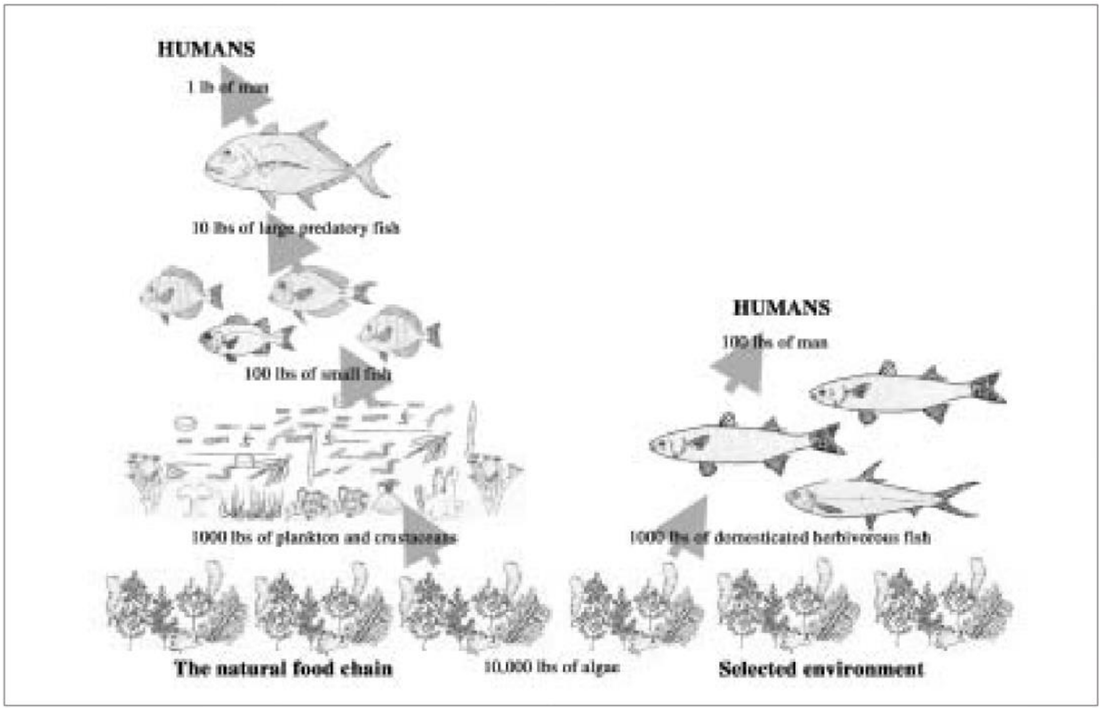

Figure 5: A comparison of energy conversion ratios between the natural environment and a selected environment. Less energy is being lost for the selected environment due to less trophic levels. From Kikiloi (2003).

Table 5: Hatchery Development

Answers	# of Interviewees	Interviewees
Funding from legislative	2	DH, CC
Using lower trophic-level species	2	DH, CC
Using wild broodstock	1	CC
Genetic marker development	1	CC
Challenge of raising hatchery fish in ponds	1	KK

3.4 POLICY OR GOVERNANCE

Two out of the five interviewees discussed the disconnect between policy and Indigenous knowledge, as well as a growing movement in the integration of Indigenous knowledge. Snow (2025) discussed how there is a gap in between Indigenous Knowledge and policy making, as many of the people from outside of Hawaiʻi who are in those decision-making positions do not have an understanding of local values, leading to friction between government agencies and the local community. Snow (2025) discussed current laws pertaining to water use. He talked about the state prioritized homes and military bases despite the state water code protecting traditional Hawaiian uses of water (i.e, loʻi, loko iʻa , etc.), raising the issue of enforcement (Snow, 2025). However, Lai (2024) notes how there is a growing awareness of this disconnect, and how avenues for chipping away at prohibitive policies are opening up as restoration increases. She provided examples, such as an amendment made in Honolulu County that allowed for caretaker residences to be built by fishponds (Lai, 2024).

Table 6: Policy or Governance

Answers	**# of Interviewees**	**Interviewees**
Disconnect between policy and Indigenous knowledge	2	BL, DS
Indigenous knowledge in fisheries management	2	BL, DS
Addressing laws on water use	1	DS

3.5 RESTORATION STRATEGIES

Two out of the five interviewees emphasized upland restoration. Both Lai (2024) and Snow (2025) discussed the interconnectedness of upland systems, which include loʻi and forest systems, and how they aid in replenishing aquifer systems in addition to providing freshwater and nutrients to loko iʻa . In addition to upland restoration, Lai (2024) reinforced the idea that hatcheries should be considered alongside broader fisheries management policies, including seasonal restrictions and spatial protections ("buffers") around loko iʻa . Furthermore, Snow (2025) emphasized the need for community empowerment as a way to address the larger issue of watershed management and water quality issues, stating how natural resource management should incorporate and align with Hawaiian values of ʻāina momona.

Table 7: Restoration Strategies

Answers	**# of Interviewees**	**Interviewees**
Upland restoration	2	BL, DS
"Buffers" outside walls	1	BL
Improving water quality	1	DS

3.7 SYNTHESIS OF FINDINGS AND SMALL-SCALE IMPLEMENTATION

According to Brown & Day (2002), many different strategies exist for addressing post-release mortality among hatchery-raised fish. These include life-skills training, environmental enrichment (raising captive fish in realistic, natural environments), and soft-releasing fish (Brown & Day, 2002). An example of some of these strategies in use can be seen in the hatchery program in Waikalua. The pua ʻama are raised in water from the loko iʻa , which allow them to grow up in a protected environment while also acclimating to the conditions in the loko iʻa (Voice of the Sea TV, 2024). This also allows for environmental variables to be controlled that otherwise are uncontrollable in loko iʻa (Voice of the Sea TV, 2024). Additionally, nitrogen generated from fish waste fertilizes the limu in the tank, allowing for the pua ʻama to feed off of the limu rather than the food pellets (Voice of the Sea TV, 2024). Furthermore, the nursery system utilizes an integrated multi-trophic aquaculture (IMTA) with sea cucumbers and manila clams being used to filter out the water (Voice of the Sea TV, 2024).

Numerous small-scale hatcheries are operated throughout Southeast Asia, and work better as a cost-effective method that focus on hatchery and nursery aspects of fingerling production, with eggs being supplied from larger hatcheries (Sim et al., 2005). Some of the advantages that Sim et al. (2005) lists include low capital input, simple construction, flexibility in terms of the types of species used, and quick economic returns due to low capital input. Applying it to Hawai'i, a small-scale hatchery system could be utilized throughout the loko iʻa network facilitated by KUA (Figure 6). Fisheries research centers such as OI or AFRC could supply the brood stock, with loko iʻa being the middlemen for nursing the fingerlings into a suitable size for release. Having small-scale hatcheries alongside loko iʻa restoration could maximize the number of fish being restocked into the wild.

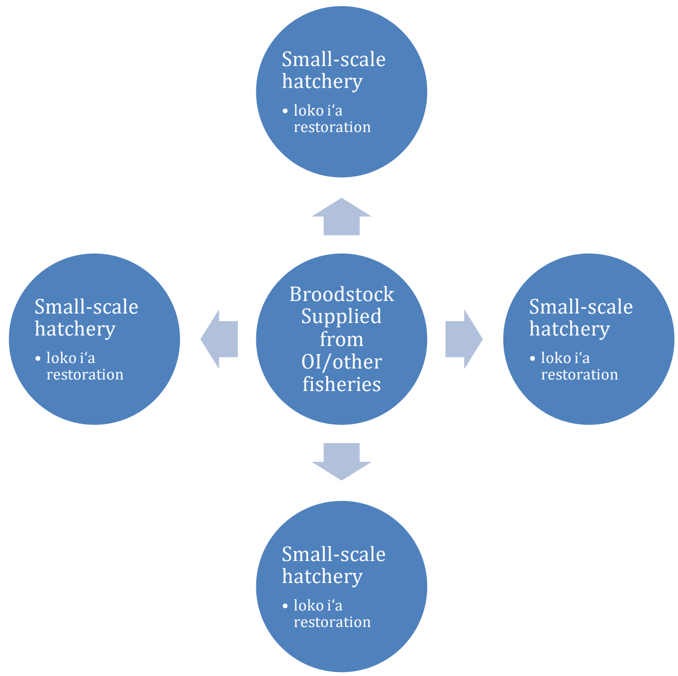

Figure 6: A hypothetical small-scale hatchery system that could be used in Hawai'i. Adapted from Sim et al. (2005).

3.7 LIMITATIONS

As stated in the Methods section, my research consisted of both expert interviews as well as literature review. As there were only 5 interviews conducted due to limited time, this thesis draws from limited sources of information spread throughout different areas. As such, they do not paint a comprehensive picture of the issue in its entirety. To improve upon that aspect of the study's methods, a larger pool of people would have to be interviewed, ensuring that they cover different perspectives on hatcheries in loko iʻa . Additionally, the results mainly discuss loko iʻa on ʻOahu due to both the framing of the questions as well as knowledge limitations.

With regards to the literature review aspect of the project, sources were mainly accessed via the UHM Library though Google Scholar. Currently, there are simply limited sources regarding knowledge on loko iʻa and other forms of traditional Hawaiian environmental management. Expanding the scope of research through a more thorough literature review (i.e., looking at newspapers, analyzing moʻolelo and oral histories, interviewing kupuna, etc.), as well as conducting fieldwork (i.e., mapping out the distributions of ʻamaʻama and other cultured species, determining population trends, etc.) would strengthen this thesis.

4.0 CONCLUSION

In summary, fish hatcheries present both opportunities and challenges for enhancing fish recruitment in loko iʻa . While they offer a potential solution for increasing fish populations and supporting aquaculture efforts, concerns about ecological balance, genetic diversity, and long-term sustainability remain. The diverse perspectives across loko iʻa caretakers, researchers, and policymakers highlight the need for an integrative approach that combines hatchery use with habitat restoration and traditional Hawaiian resource management principles. To maximize effectiveness, future efforts should prioritize small-scale, community-led hatchery models that align with local ecological conditions and cultural practices. Additionally, further research into hatchery-reared fish survivability, stakeholder collaboration, and funding mechanisms will be crucial in determining the feasibility of hatchery integration. Overall, the success of fish hatcheries as a tool for recruitment in loko iʻa will depend on a balanced strategy that incorporates Indigenous knowledge, scientific research, and sustainable aquaculture practices.

APPENDIX 1

Interview Date: 11/5/2024

Interview Location: Zoom

Interviewer: Kade Jacang

Interviewee: [Brandi Lai]

Kade: For brief introductions, my name is Kade Jacang, and I'm currently a senior at UH Manoa majoring in Global Environmental Science. The purpose of this interview is to (…) it's for my thesis, which is evaluating fish hatcheries as a method for juvenile recruitment for loko iʻa , and that involves literature review as well as interviews with experts of various backgrounds, and I'm evaluating different aspects that go into hatcheries such as environmental and economic, as well as social and cultural.

[Brandi]: I'm [Brandi Lai]. I'm from ʻEwa, and I work for [a non-profit organization] and our acronym means backbone, so we talk about ourselves as a backbone organization for many community networks of malama ʻaina efforts across the island, and one of those organizations is [a network of fishpond caretakers and stewardship organizations], and serve as the coordinator for that network for about 10 years now.

Kade: Could you provide a brief overview of the history and traditional practices of loko iʻa (Hawaiian fishponds)?

[Brandi]: I guess we can think about fishponds as an evolution of technologies across the Pacific, and I think practitioners like to think of it as the highest form of those technologies, innovated out of the resourcefulness of our ancestors and the limited resources of just living on islands. The practices of loko iʻa range from the fact that they have different physical structures, and so they serve different functions and are unique to the places they were built, but an underlying theme of loko iʻa is that the knowledge and innovation to employ these technologies was based on knowledge of the environment, and thinking of loko iʻa as a way to optimize those environments. And so, a lot of those core elements of loko iʻa are optimizing estuaries, so being in places with freshwater sources, optimizing their role in the ahupuaʻa, knowing that a well-functioning fishpond relied on really good functioning and management of watershed, upland agriculture and agroforestry systems, and also relied on good social and political structures to employ the manpower to build them. And also just knowing that they have integrated practices with wild fisheries surrounding them. Some of the practices that people associate with loko iʻa today are in places where there are pōhaku (uhau humu pōhaku, which is traditional dry-stacked masonry). Other practices… acknowledging that loko iʻa were passive systems but also highly managed systems in that they relied on the constant observation of the caretakers and the kiaʻi, the constant management of the water resources.

Kade: How do you see the role of hatcheries in relation to the traditional management of loko iʻa ?

[Brandi]: Depending on how broad you're casting the net for these interviews, you might be able to see the diversity of opinions within practitioners. I think some practitioners feel that hatcheries should not play a role because they believe that by restoration of habitat, and by caretaking of the fish populations that we have, the natural recruitment cycles of these fish that people talk about as how loko iʻa were stocked can be revived, and there are those that believe that hatcheries can play a role in jumpstarting or helping to provide the fingerlings that would have been recruited into fishponds. And understanding what my role is for the network too is that [a non-profit organization] and me are not fishpond managers/caretakers; my role as a coordinator is to understand the shared opportunities that they have as well as any common concerns and issues with any given topic (not limited to just hatcheries), and then to try to find the opportunities to make things happen (making it into a shared opportunity or to address common concerns or issues), and so what I'm reflecting back to you is that there is still this diversity of opinion within the hui, and (to me) it's unclear how big of a role hatcheries will play in the future, but everyone sees that they could play a role (a tool in a toolbox; not everyone is sure how they want to use it).

Kade: It is kind of interesting because I have heard that it is also a matter of preserving the cultural integrity of the loko iʻa , and with climate change and shifting populations of a lot of the fish, there might be a greater use for hatcheries in the future, but it seems like a case-by-case basis for different fishponds.

[Brandi]: Yeah, yeah. And it's not even just future climate change, it's like-you know how I said earlier that fishponds rely on good management of the mauka areas? Over-development has honestly changed those land uses. The social and political changes that have happened in Hawaii have forever changed the landscapes of the watershed above many of these loko iʻa . People are taking into account that land use is different than what it was traditionally, our water resources are really different, and the role that freshwater plays are a huge factor (in loko iʻa), and we are learning about the role of freshwater on the biology of the fish raised in fishponds, and so I think yes, accounting for future changes in the environment, but also acknowledging that our present environment is different than when fishponds were built, and what are the ways that we can adapt so that these practices can be continued? Perpetuating the traditional cultural values into the future even though the technological and physical operations may be different? And better understanding of the wild populations.

Kade: How important is community involvement in the process of integrating hatcheries into loko iʻa management? What steps have been (or will be) taken to ensure local stakeholders are engaged?

[Brandi]: There would have to be a lot of engagement; I think community members even beyond the fishpond practitioners would like to better understand hatcheries and other aquaculture technologies in general. Fishponds also have an open relationship with outside fisheries too, and there is a concern for what it means for natural populations to be using fish raised in hatchery facilities for an unknown amount of time/generations, and

I learned that there are safeguards to ensure that those issues do not occur, but not many people know about them. So it is also an outreach/messaging issue also.

Kade: I feel like with what you do, it's important (when loko iʻa are more restored) to inform the everyday person on what's going on, how they can support, what it means for the environment as well as food security.

[Brandi]: Yeah, because I think that fishponds are more well-known now, and a lot of people support the idea that fishponds can be a part of our food sustainability as a broader community someday, and so I think people would want to know how they can make it happen and what are the barriers to that.

Kade: Are you aware of any policies or regulations that currently govern the use of loko iʻa development or fish recruitment? Are there any changes you believe should be made?

[Brandi]: Also as a broader shift in the recognition and incorporation of indigenous knowledge and practices, I think nationwide we are seeing (at least in this federal administration) the recognition of disconnects between environmental policies and indigenous knowledge. For one example, recently the advisory council on historic preservation made an exemption for work on historical properties concerning permitting for the stewardship of certain sites like wahi pana. There are also mandates that agencies have to work towards co management and stewardship with native tribes on their park lands. There is a broader movement of chipping away at regulatory barriers that exist for loko iʻa as well as wahi pana and loʻi (they ran into problems with protected species). And yes those things do exist and they can be a barrier in specific cases, but the overall growth in these restorations opens up avenues to chip away at those prohibitive policies. It also includes building relationships over time with the people who work in those regulatory agencies and have the mindset to work though the bureaucracy of dismantling those policies. Recently, in Honolulu County there was an amendment for land use ordinances that allowed for caretaker residences to be built adjacent to fishponds, and it would be great to see this extend to other counties as well, as it is an ongoing issue in the agriculture sector (for fishpond, there needs to be constant management). Not many fishponds have leases from the state, and it's an opportunity for communities to work with the state to better steward these properties, and to rethink the way that fishpond properties are leased.

Kade: How do you think modern (aquaculture) hatchery practices can be harmonized with traditional Hawaiian methods of fishpond management?

[Brandi]: (Talking about integrating modern aquaculture practices in general) The example I was thinking of was the dredging of fishponds. Because a lot of them are at the bottom of the watershed, they have turned into sediment basins because the mauka land uses have changed. In general, upland areas like loʻi and irrigated agriculture (in places with regular water) would be the sediment basins, and nutrients would be absorbed by the loko iʻa as the water flows into the ocean. In many communities with either plantation culture or housing development, many of those loko i ʻa are filled in with sediment and don’t have the right kinds of habitats to support these fish. Even separate from the water conversation, these places have been filled in for decades, and people say that these ponds would have to be dredged. I think that manual raking or walking through (hehi hehi) has been recognized as traditional maintenance practices to regularly get sediment out of fishponds. A few ponds (less than 5, I’d say), have done either pumping or physical dredging of sediments, and I think that’s something that has evolved over the years, like not a lot of people were talking about dredging (maybe 10 years ago), but now it is a realistic thing that they would have to consider (“Do they want to go down that route?” “Is it necessary for their location?” “Can they afford it?” “What are the impacts to the surrounding area?”). There are ways that they can do sediment removal, and they would have to do it as a result of decades of negligence and mismanagement before.

Kade: I was talking with [Ken] a couple months ago, and one of the big issues that they had aside from water quality was sedimentation. He talked about how the pond was deeper back then, and it's harder to dredge because it is smaller compared to other fishponds, and I am not sure if dredging would be a viable solution.

Kade: Are there any alternate priorities that we should account for when it comes to fish recruitment?

[Brandi]: Some of the things that I’ve heard was that to get the fingerlings you have to protect adults that are going to spawn. Fisheries management is a piece of that, looking at the fishing rules for target species (looking at the season times, for mullet). The fishponds have floated this idea of establishing buffers around fishpond walls (haven't decided how far out, or what it means, but some kind of recreational/fishing activity restriction around fishpond walls). Those are fisheries management kinds of tools that could contribute to a natural revival of recruitment. And of course, the restoration of freshwater, knowing the role that freshwater plays in fingerling recruitment to shoreline areas. These two things stand out to me as restoration methods that help in recruitment. Restoration could also extend to other environments (i.e., forests aid in recharging aquifers).

APPENDIX 2

Interview Date: 11/25/2024

Interview Location: Zoom

Interviewer: Kade Jacang

Interviewee: [Diana Holt]

Kade: Could you give a summary of the [High School Marine Science Program] and their mission?

[Diana]: [The high school marine science program]'s mission is to empower [ʻEwa] Youth to be ʻāina-minded individuals with the desire and ability to fulfill their kuleana to themselves, their family, community and world. We use a functioning saltwater aquaculture facility to teach students workplace and problem-solving skills. We are part of a DOE eduprise pilot program and use the facility also to raise species that are marketed to provide funds to support the facility and student activities. Students learn to collect and monitor water quality data to keep species in optimal health and at maximum growth potential.

Kade: How was your experience coordinating with the Oceanic Institute for juvenile mullet?

[Diana]: We have partnered with OI for 30 years. They have provided us support through donation of species and advice and expertise when we have run into problems. We contracted with OI to conduct two mullet runs using funding we received from DAR. Last year's run provided us with approximately 9000 pua ʻama and this year's run is expected to almost double that amount. The pua ʻama from last year's run went to fishpond on Oahu and the Big Island. We have had a positive experience working with OI. Through KUPU and DAR funding we have had a former student trained at OI as a hatchery technician and he helped to make last year's run happen and is working on this year's run.

Kade: How has the relationship started, and how did it evolve over time?

[Diana]: Okay, so it started (…) I guess it's been about 30 years also (…) when we got the saltwater well, and we were developing the curriculum for the program, we reached out to Oceanic Institute; [Sasha Lin], the teacher who started the program, did a summer workshop that was put on by OI when they had a facility on Kona, and that was our introduction to [Grant Kent] and [Maria Trent], and that's who I first started working with. They used to run workshops for us, a 3-day workshop in Kona and we would take the students on a field trip to the big island and work with OI for 3 days in an intensive aquaculture workshop. They also generously supplied us with shrimp, with mullet when they had them, and they have the expertise; any questions we have, they have always been very helpful to us.

Kade: Yeah, and I saw that last year there were 9000 of the keiki?

[Diana]: Yeah, so there was a bill introduced into the legislature for the past 2 years to establish a native fish hatchery here at [a high school in ‘Ewa]. Unfortunately, it didn’t make it through either time. I’ve been working with KUA, and we're going to introduce the bill again this legislative session and see what happens, and hopefully we get the hatchery. Our principal is very supportive, and she already has an area where the hatchery is going to be, and it will be fenced in this school year, so the area will be ready for the hatchery if we get the funding. It will also increase the space for the production of our seaweed and fish.

Kade: What were some of the challenges with getting the hatchery up and running? What lessons did you learn?

[Diana]: At this point we do not have a hatchery here on campus. Bills have been introduced in the past two legislative sessions but unfortunately, they were not funded. We are working with KUA to again introduce a bill this year. There are two big challenges to get a hatchery up and running. First getting the funds to create the hatchery. The last estimate to get just the physical structures up is around 6 million dollars. This does not include outfitting the hatchery with tools and equipment. The second big challenge is staffing. If we cannot get permanent positions with good benefits, it will be hard to recruit, especially for the hatchery manager.

Kade: What are some specific challenges regarding funding?

[Diana]: We got funding from the ledge; this is the third year of it, the last year of it, but we got $855,000 a year over the span of 3 years. Some of it was used to get supplies for the hatchery, some of it is still sitting in DOE facilities (around 1.2 million), and it's not enough to get started, so it's kind of just waiting until we get more funding, and then we can proceed with the project. If it doesn't make it through the ledge this year, then I'll have to sit down with our stakeholders and decide how we will use the money because it can't sit indefinitely, from what I understand. I got money from DAR, and I used that money to pay OI to conduct 2 runs (last year and this year). Last year we had 9000 juvenile mullets, and this year they're predicting 15,000 to 25,000, and we should be receiving those fish January-February next year. We'll keep some of them here, but I'm currently working with loko iʻa around the island and around the state to see where the fish are going to go. We can hold them temporarily when they're small, but we don't because my tanks are also used for my ogo and tilapia production and student projects,

Kade: So, it's just a matter of trying to get the mullet out to other places?

Diana: Yeah, because when we get them, they're very small, and you can't stock them in a fish pond at that size; they'll just be food for other fish. So, what we need is our places. [Ken] calls them "pua boot camps", where they can grow up adjacent to the pond where they're going to be released when they're big enough. So, I've been working with [Ken] and [Brandi] from [a non-profit organization] to reach out to organizations that would potentially want the fish, and also with DAR; there is another chunk of funding through them that we haven't decided on how we will allocate it.

Kade: One of the interesting things I’ve heard about the pua boot camp is how they approached increasing the survivability of the pua, mainly in that they filter out all the bigger viruses or pathogens and get the pua accustomed to the environment that they’ll be released in. I guess what I’m thinking is, if pua boot camps were implemented it would be a placed-based solution because the water quality would vary from pond to pond.

[Diana]: Yeah, that was one of the biggest problems we had with last year’s 9,000. Because they’re coming out of OI, they’re in 30 ppt saltwater, and most fish ponds that they’re going to are between 3-10 ppt saltwater. You can’t take a 30 ppt fish and just pluck them into the water, you have to transition them. It takes a lot of tanks to be able to slowly transition them to go to the fish ponds. So, to me that’s the primary purpose of the pua boot camps. If they’re coming out of the hatchery at higher salinities, you have to have a mechanism for transitioning the fish to ensure high survivability when they go into the actual pond.

Kade: With regards to hatchery, are there any major concerns with environmental impacts such as the interaction with hatchery and wild-caught mullet?

[Diana]: That’s a good question. When we met with KUA and stakeholders from the fish ponds, one of the things was “Is it okay to release OI’s broodstock from the Big Island in Oahu?” So, when they’re going into a pond, it's a bit different than general stock enhancement where it’s going back into the wild. I think that's a discussion probably above my pay grade, but that’s definitely something to keep in mind. The main objective of our hatchery at [a high school in ‘Ewa] isn’t to be a moneymaker. As an island, the better equipped we are to raise our own protein, the better off we are. As fish ponds are being restored, we need mechanisms to provide native fish to the fish ponds, because the recruitment of native ‘ama‘ama is not great. It’s like 70% invasive and 30% native, and you can’t distinguish between the two at a smaller size, and you can end up stocking a fish that's not native.

Kade: I also feel like having to distinguish between native and invasive species would also contribute to funding issues because that’s just an additional cost on top of everything else.

[Diana]: Yep, yep. That’s true. My hope is that when we get the hatchery, in my personal opinion it should be state-funded, run and staffed by DAR, and that there needs to be a clear process that decides where the pua would go because it should not be [a high school in ‘Ewa]’s choice. There should be an objective panel that decides where the greatest need is, or where the highest percent of survival is going to be for the fish. However, the decision process is, there needs to be something in place.

Kade: Do you work closely with other loko i‘a across the island?

[Diana]: Not closely but we have worked with both He‘eia and Loko ea fishponds. We have also worked with [Charlie Kane] at Maunalua fishpond. Some of the DAR funds went to him so he could set up a pua boot camp. Pua boot camps are critical as if we do get a hatchery established at [a high school in ‘Ewa], we will not have the space to raise the ama to a big enough size so they can be released into ponds. Some of the pua ‘ama from last year went to Loko ea.

Kade: What role do workshops or events play in fostering communication between loko i‘a caretakers? Between caretakers and the outside community?

[Diana]: I can speak for He‘eia and Loko ea. I think they are excellent with their educational programs. They need a source of income, so there’s a fee usually when you want to take a group to learn from them. But if they know that a school has a difficult time coming up with the funds they’ll waive or reduce it. With Loko ea, they have a wide menu, and you can do a lot of things as a teacher depending on your objective. And He‘eia is the same way. They really want young people in particular to understand what fish ponds are and to be vested in the fish pond’s health.

Kade: Have you considered establishing hatcheries for other native fish like moi or awa? How might they differ from raising mullet?

[Diana]: A hatchery can be used to raise any marine species that it gets fertilized eggs from. The limiting factor for the species is what feeds are needed for each stage of the species’ development. As long as the live larval feeds are manageable, any species that has its life cycle closed so we know what feed is needed at each stage can be raised in a hatchery setting. Mullet from my understanding is one of the more difficult species to raise as it is difficult to get to spawn. Awa is relatively easy. If we get a hatchery here at [a high school in ‘Ewa], it is our belief that it should be used to provide species desired by fishponds so they can be stocked at levels that allow them to once again provide healthy protein to our Islands and to increase our food security.

Kade: Based on your experience, what best practices would you recommend for those considering hatcheries as a tool for fish recruitment in loko i‘a?

[Diana]: I am not familiar with the range that hatcheries can span. I don’t have experience with any hatchery except the one at OI. I am sure there are some low-tech options but I don’t know anything about that. Since mullet is probably the most desired fishpond fish, I am not sure a low-tech hatchery would be successful. I think [Ken] would be better able to answer this question.

Kade: What are the most common mistakes or misconceptions people have about hatchery operations?

[Diana]: I know there have been concerns on offshore cage culture, negative impacts from freshwater hatcheries/fish production, and that’s kind of out there. That’s a very difficult question for me to answer, since we have a clear picture and feeling about production for sustenance. If something happens and the ships stop coming, we don’t have a lot of food on our islands to sustain us, so it’s something we constantly need to be aware of. And mullets are ideal because they're herbivores. They're a low investment in terms of protein/feed, so if we can get the populations up, then we can start recruiting naturally through the mākāhā like the fish ponds are designed to.

Kade: For moi and awa, are they higher in terms of trophic level?

Diana: Yeah, yeah. Awa ʻaua I know are fish pond fish too. Moi I'm not so sure because they're carnivorous and surge fish. So, they (moi) have high DO demand, and we've gotten them from OI before, and I've stopped asking them because we lose power out here frequently, and every time we lose power we lose a whole tank of moi because they cannot tolerate the low dissolved oxygen (DO). Until we get a backup generator, I'm not going to do moi. Tilapia, which is what we do now, are hard to kill.

Kade: How can traditional ecological knowledge and modern science complement each other in hatchery practices?

[Diana]: I think that one of the things we need to keep in mind, as we have all of this technology to collect data on different fish ponds, is to not lose the most important ingredient: to kilo, which is to observe, to keep our eyes and other senses open to events within a loko iʻa. Relying purely on data does not paint a full picture of events, and it's something that takes years to develop; getting to know your space (i.e., what it should smell like, feel like, etc.), and passing on that knowledge. And with our aquaculture facility, all of the tanks hold different species, and are analogous to fish ponds. You would have to know what each individual pond should look like, smell like. And so, I think keeping in mind that human observation is just as important as the physical data you collect. And being observant and in tune with the environment is key to being able to make good observations.

Kade: How do you see the future of hatcheries in the context of loko iʻa and broader fishery management practices in Hawaii?

[Diana]: With the introduction of more invasive species and the continued overfishing of our waters I think hatcheries are critically important going forward. When recruiting mullet from the wild a significant portion of the catch may be the invasive species not the native Hawaiian mullet. Without DNA testing it is difficult to distinguish the species until they are of a larger size. What is produced in hatcheries is known to be native so it eliminates that problem. There also needs to be a discussion about stock enhancement. As numbers in the wild decrease releasing hatchery raised mullet and other species can help restore populations.

Kade: Could hatcheries become an educational tool to reconnect younger generations with loko iʻa traditions?

[Diana]: Yeah, I really do, and it's our hope to have it be run by scientists, as we don't have the expertise to operate them, but we would like to have students intern there to spend time with the scientists running the hatchery in order to learn their skills for work.

We have one of our former graduates from our program, and it's his third year at OI as an intern. And it's so great because we have him come here on his off-days and work with our students, and he teaches them how to grow brine shrimp and rotifers, because that's his job. So yes, I think it's really important that the hatchery be used as an educational tool to get kids thinking about why we need them in the first place, what we will do as younger people who're coming up and controlling the world, and what decisions we can make.

Kade: I feel like with hatcheries, because you noted that one of the challenges of getting a hatchet up and running is manpower, it helps in that regard to get students thinking about positions within aquaculture and potentially can find jobs there or other opportunities.

Diana: Yeah, I mean just algae-related jobs in general, there's thousands of them available, and I think our kids don't recognize how high-level their skill is in terms of working with algae. They don't understand that they know so much more than what the average person does; they understand what water quality is, why we monitor it, algae counts, and they possess a whole range of skills that're definitely workforce skills.

Kade: Yeah, I know that it was University of Hawaii at Windward that actually has a program for limu.

Diana: Yeah, they were working with [Jane Doe], who was at Windward. We're working with Windward to try and get the Hawaiian Studies course. We wanted to offer it this upcoming spring semester, but that didn’t work out, so we’re probably going to offer it next fall, so hopefully that will work out and our kids will be able to get dual credit for taking the course. So yeah, they’re in the process of developing the curriculum, so I think they're going to have both a two-year and a four-year algae certificate or degree.

Kade: What policy changes or incentives could better support the loko iʻa community in adopting hatcheries?

[Diana]: I don’t know the range of hatcheries, because a hatchery has a lot of different meanings. It can be high-tech, it can be low-tech, although I’m not sure how a low-tech mullet hatchery would be. Mullet, from what I understand, the most difficult part is getting them to spawn in captivity. I know it's expensive, and they inject a hormone to induce spawning. And so that's going to take a level of expertise. In terms of policy, I don't know enough to answer that question.

APPENDIX 3

Interview Date: 11/26/24

Interview Location: Zoon

Interviewer: Kade Jacang

Interviewee: [Chad Cullen]

Kade: How do you see the role of hatcheries in relation to the traditional management of loko iʻa?

[Chad]: Traditional loko iʻa relied on the wild recruitment of juveniles to come into the fishpond, and they would manage these ponds (maximizing recruitment and minimizing predators). The challenge now is that there is limited recruitment as loko iʻa are being restored. The wild populations of mullet and other species that would normally be recruited into the pond are lower than it used to be historically. And so, what we're trying to determine is if hatcheries could provide those juvenile fish into the fishponds to augment their productivity, and get them kick-started with the hope that those fish can grow in the pond Directly stocking ponds, or stocking fishponds and wild populations. Some percentage of those would be released and become wild adults and help boost the population in that manner. I see that there's two possible ways that hatcheries can kind of fill the gaps here. One would be direct stocking of the fishponds so that they can harvest them, and the hatcheries would be a continuous source of fingerlings for the fishponds. The second way would be for hatcheries to help stock the pond, but at the same time help boost the wild stocks so that eventually the hatcheries would conceivably put themselves out of business, as there'd be enough fish in the environment to seed the fishponds.

Kade: Are there any concerns about genetic diversity or the health of fish populations when using hatcheries in these traditional systems?

[Chad]: That is something that needs to be taken into consideration, for sure. One way that can mitigate the problem is to develop genetic markers for the species that you're working with (i.e., mullet). I know that there is a project going on right now that the state is supporting to collect samples of mullet from different portions of the island, and then hopefully develop a genetic marker that can be used as a tool to ensure genetic compatibility between hatchery and wild populations, and to ensure that the genetic diversity is consistent with what's already out there. So, to answer your question: Yes, there is a concern.

Kade: What steps have been taken to ensure local stakeholders are engaged?

[Chad]: So, we've relied on fishpond partners to do that. The work up until recently has been localized at just a few fishponds; the fish produced and released back into these fishponds are a small number. And so, we've relied mostly on fishpond practitioners to work within their network of associated individuals who may want to be informed about that and want to understand what's going on and that kind of thing. That's largely how we've done it. Looking ahead, we're going to need to do broader community engagement, so we’re going to be working with the state and with agencies like KUA and Sea Grant to message what’s going on, why it’s important, and what we’re trying to address.

Kade: What are the most critical factors to consider when selecting fish species for hatchery programs intended for loko i‘a?

[Chad]: So, we have not, I've never, I personally have not worked with awa, but there were prior researchers at Oceanic Institute that have. And that is a species, that is a species that can be cultured, just like mullet and moi. So, the species I've worked with are the striped mullet, and the moi, *Polydactylus sexilis*. Those are the two species that have been produced, commercial quantities, hundreds of thousands, you know, at a time, and have been used for stock enhancement projects, as well as commercial aquaculture activities. The other species I'm working with currently is aholohole, the Hawaiian flagtail. So, but those methods for producing that in large quantities haven't really been established yet. So, we're just, just really getting started with that species. So, one of the big concerns in loko i‘a is they want to have fish species that they don't have to feed. So, mullet, you know, are herbivores, they consume diatoms, they consume benthic invertebrates, things like that. And so, that's a species of real interest, because the juveniles can go into the fish pond, and then they can just feed on the natural productivity within the fish pond. And ideally, they don't need any supplemental feeding. The challenge with other species like moi, or any other carnivorous species is that they likely would require some type of supplementary feeding. And then that causes nutrient problems in the fish pond and also causes costs and all kinds of other things that would be incurred by the fish pond staff. So, although moi historically have been raised in fish ponds, typically the numbers of moi are not very high. There's the moi that do kind of recruit into the fish ponds, just feed on, there's enough wild food there for them to feed on. And so, I don't know that we could introduce moi in like a significant quantity, because I don't know that there would be enough natural productivity for them to feed on. So, that's one of the big considerations, if the fish pond wants to feed the fish or not. If they don't want to feed the fish, then providing fish, either at a low density and typically a lower trophic level fish, like an herbivore would be the ideal candidate. If the fish pond does want to feed the fish and maintain them in more of an intensive manner, then other species could be considered. There would be higher costs going into that.

Kade: Have you observed any differences in behavior or survival between hatchery-reared fish and those naturally recruited in loko iʻa?

[Chad]: We haven't. I should have pointed out, one of the reasons we don't see a big difference is because we intentionally use wild broodstock. So, the parent fish are fish that were collected from the wild near the origin of where the juveniles are going back. So, they're only an F1 generation. So, they're basically the offspring of wild parents. So, you really don't see any difference in that case, unless you, or you typically don't see much difference in the morphology of the fish or anything like that, unless you get into multiple generations of subsequent families, and then you can start to see some morphological differences sometimes or some subtle differences in behavior, but we haven't observed anything like that. So, they basically look the same and act the same as the wild mullet that I've encountered anyway.

Kade: What are the economic implications of using hatcheries for fish recruitment in loko iʻa? Are they cost-effective in the long term?

[Chad]: I guess it depends on how and where you put the value. You know, I don't know that they certainly can't support themselves. Like, the fish that they're producing typically would not be produced in a manner that their market value, their direct market value would cover the costs of the production, unless you're at quite a large scale. So, from that standpoint, they're probably not cost-effective. But if you look at the ecological value and the potential downstream value to restored ecosystems and that type of thing, then that's where I think you can start to say that perhaps they are cost-effective if they're restoring ecosystems that then have a long-time legacy of being productive. So, I think it's kind of a hard question to answer empirically, but typically these things are not financially solvent. Like, typically most stock restoration hatcheries are subsidized by some type of government funding or some type of third-party support. They're not being supported directly by the people buying, paying for the fish.

Kade: Yeah, because I did conduct prior interviews and then when I asked the question, they may raise, or they may produce more for more of a subsidence need and rather than like an economic need. So, yeah, I feel like in that regard, it's more of a long-term value that I think people need to be more aware of rather than more short term value.

[Chad]: Yeah, and typically these types of things take decades too. They don't, they're, you know, we're not going to just produce fish for one year or two years and then that's going to be enough and we'll never have to do it again. You know, that's the models that we've been looking at seem to indicate like, you know, kind of five years, 10 years, like that kind of timescale is what's going to, it's going to take time to see an ecosystem impact. And then depending on how long you sustain it would determine kind of how big the impact can be, right? So, the longer you do it, the bigger the impact, perhaps the more value you get back for what you've invested.

Kade: And I guess in that regard, do you think there's any, I guess, cheaper alternatives for fish recruitment from Mullet or do you think that we should prioritize other needs such as restoring upland systems?

[Chad]: Right. Well, I think they go hand in hand. I mean, it's kind of a chicken and the egg situation. So, I don't think it makes sense to just dump lots of fish out into the ocean unless you have restored habitat for them to recruit into and to potentially become reproductive and start contributing back to the population. So, I think you have to restore the habitat, but, and that's what's been happening. So, the fish ponds are kind of restoring these critical areas for fish habitat. And that includes the upland areas too, because they work hand in hand. You know, the freshwater is critical into the fish ponds for sure. That's what drives all the primary production. So, you need both. But I don't think that just restoring the habitat is the answer either, because basically that's what's been happening over the past 20 or 30 years. A lot of effort is going into restoring habitat, but they're still not seeing any benefits for recruitment. So, I think that's where kind of incorporating the two of these activities makes a lot of sense. Let's see. And then as far as cheaper, as far as cheaper alternatives, I mean, the cheapest alternative is to just tell people they can't fish anymore. You know, that doesn't really cost a whole lot. And it, and if you reduce the fishing pressure completely, you could conceivably probably eventually get back to a restored larger population. But I don't know that the public's going to be okay with just stopping fishing completely.

Kade: Yeah. I feel like that's also more sort of a fisheries issue, kind of just having to regulate some of the laws that are already put in place, or yeah, more regulation and more enforcement of those laws that are already put in place.

[Chad]: Right, right. And those regulations have been there for the past 20 or 30 years, and really, it's not making much difference. It's just kind of keeping the population flat. It's not, we're not seeing any kind of increase.

Kade: How do you address potential disease risks associated with hatchery-reared fish in loko iʻa systems?

[Chad]: Yeah, so I think that there might be a little bit of a misconception or I don't know. I don't want to say propaganda, but you know, there's definitely a public perception out there that hatchery produced fish are loaded with diseases. They're loaded with all these problems. And I don't think people realize that that's not the case at all. If that were the case, the hatcheries wouldn't work. Like the fish would all be perishing in the systems. So, it’s not that way at all. In fact, most hatcheries are very careful in biosecurity operations and standard operating procedures to exclude and prevent pathogens from getting into their facility. And if they do find anything, they're really quick at kind of eradicating them so that the fish are healthy. So, I guess that's twofold. One of the ways we minimize the pathogens is by assuring that there just aren't pathogens in the facility. So, we try to maintain a bio-secure facility that doesn't have a prevalence of pathogens. And that's done by routinely screening the fish, sampling the fish. We have veterinarians that can assess the fish for health and any known problems. We can kind of be sure that there's no presence of those known issues. And then before the fish are released, typically a subsample of the fish has to be sacrificed and more fully investigated for the presence of any external or internal pathogens that might not be known to basically assure that the population is free of those issues. So, that's a long way of saying the facility has protocols and procedures to exclude pathogens. And then the fish before they're released are subsequently checked to make sure that there are no pathogens present. And that's really important because no hatchery wants to be releasing fish out into the wild that are going to cause problems. The whole point of producing these fish is to help the environment, not to hurt it.

Kade: How has that misconception arised with hatchery fish being viewed as having diseases?

[Chad]: Yeah, I'm not exactly sure the origins, but there have been cases and occurrences in all forms of agriculture; whenever you produce large amounts of animals in a relatively small space, you increase the susceptibility or likelihood of there being problems. So if you think of crowded chickens, crowded pigs, crowded cows, there's lots of ways that those types of industries try to prevent diseases and prevent things from happening. But inevitably, if they do occur, they have to deal with it. So, I think there's the same kind of analogy with farmed fish; you have mass produced fish that are crowded in these tanks, and they probably are sick, and they're going to get out there into the wild. So, I think some of it comes from the terrestrial agriculture analogy to aquaculture. But some of it also does come from unfortunate choices made in the past. There's a history of people not paying attention to genetics, disease, and then these types of things causing problems, particularly in things like the salmon industry, for example. And I think those are the things that kind of carry over now to anyone trying to do this. There's kind of an increased scrutiny over that, and I don’t think it’s a bad thing; I think it’s good for people to be worried, but I don’t think that everything should have a big, black eye because there was some problems in the past.

Kade: What methods do you use to monitor the survival and growth rates of hatchery-reared fish after their introduction to loko i‘a?

[Chad]: Yeah. So, the hatchery produced fish can be tagged. So, they can, you know, once there's a genetic marker, that's not visible, but that's something that could be sampled. If you sample some tissue from the fish, you can then determine its origin. But you could visually tag the fish too. You know, there's visual implants, you know, that basically have a little fluorescent mark that you can put in the fish that would indicate that it's a hatchery produced fish. You could put a coded wire tag, which is basically just a wire that goes inside the cheekbone. That's pretty hard to see, but fishermen, if they know what they're looking for, can look for it, and then they could report it back. So, there are ways to tag the fish so that you know how they're doing, and then they could be sampled or caught by fishermen, and then they could report that information back. So that's largely how these types of things are done. You know, the fish are tagged in some way, and then they're sampled at some later point in time, either by the fish pond staff, or by technicians, or by the general public, you know, catching them and then reporting back information.

Kade: How did the program start?

[Chad]: We got it started out of a need. I think it was because the fishpond practitioners were basically letting us know that they wanted fish production going on in their fishpond, and didn’t really have a lot of fish going in, and this idea of producing mullet, moi, and other species for Hawaii is nothing new. It started back in the 80s and 90s, when they had stock introductions of these species. So, I think the information kind of carried over to subsequent generations, and they kind of knew that this was possible, that these species could be produced and maybe could help boost their populations in fishponds. So that’s kind of where the idea came into being. And then, it got incorporated because I was working on the culture methods for other species of fish. So, my background is in aquaculture of marine fish species, but not necessarily these species. I was working with other species of marine fish, but the methods to produce them are largely the same. And so, we were asked to see if we could support this effort by being the production center for the fish. And so, we got funding from various agencies. I think we got some funding from Conservation International, from NOAA, some other, yeah, I think those were the two big ones. NOAA and Conservation International supported the projects. And so, the one challenge is getting enough money to do it. The next challenge is biology. So, producing mullet is a little bit challenging because they won't spawn on their own in captivity. So, when you have captive broodstock, they'll mature, but they won't spontaneously release their dennings. And so, you have to basically assess them for what state of maturation they're in and then you have to induce them using argonics to get them to spawn. And so, that's logistically and labor intensive, logistically challenging, labor intensive, cost intensive. And then, the other issue is that they're seasonal. So, they only, at least mullet, only spawn in the winter naturally. So, you're limited with the time of year that you can fish. It's a relatively short season. So, you don't have many opportunities to get it right in the short time you have. So, I would say those are the biggest challenges. It takes quite a bit of money and it takes quite a bit of labor to dedicate to doing this. And so, that's why a lot of places are not doing it.

APPENDIX 4

Interview Date: 1/31/2025

Interview Location: Zoon

Interviewer: Kade Jacang

Interviewee: [David Snow]

Kade: How do you think modern hatchery practices can be harmonized with traditional Hawaiian methods of fishpond management?

[David]: Okay, well, I'm not sure you'll like my answer but to me hatcheries, are you talking like onshore hatcheries, right? (Yes) Yeah, so to me onshore hatcheries are only necessary because our ocean is so unhealthy. We certainly didn't need hatcheries in the old days. So, I mean hatcheries are a nice solution for now, but if that's all we rely on for the future then we're kind of missing the point, which is having a healthy future. So, one time, I was talking with some legislature who is interested in supporting hatcheries and like going all in on that, which you know I'm not against, but I told him like the ultimate goal is to get people to value the ocean again and to have a healthy ocean so that our oceans are actually feeding these aquaculture systems like they were designed to 800 years ago. So yeah, I think hatcheries are a band-aid solution, an important one for now but I think you can't forget what the end game is, which is a healthy ocean, healthy people. So, I'm not sure if that answered your question, but that's what I was thinking when you asked it.

Kade: So, it's a matter of integrating those traditional Hawaiian practices into our current fisheries management structure?

[David]: Yeah, I guess you could say integration. I'm not sure. Yeah, that's a good enough word. I think we need fisheries management on a large and a small scale that is aligned with Hawaiian values of ʻāina momona. And continually, artificially feeding our fishponds from hatcheries is kind of propping up ʻāina momona on a house of cards. Because whatever happens in the fishery, that means there's no fish in the fishpond. That's not what they were designed to do.

Kade: With regards to land use, would you say it's a conflict between sustenance as well as economic needs of the state?

[David]: Yeah, I think, I mean for us it's not a conflict. I mean it's, for us it's a super clear connection between how this can grow our local economy in a very robust and resilient way. But there are many people who still believe in a different economic model that tends to monetize certain things and will perceive the highest and best use of ʻāina as development. So, I would think, yeah, there's a disagreement philosophically in how to approach the economic model that's employed in our ahupuaʻa and our mokuʻu.

Kade: And let's see, I guess how could the outside community contribute to pushing or trying to push traditional Hawaiian values into our natural resource management?

[David]: Um, quite honestly, I think it will, it starts with hiring people from Hawai'i into decision-making positions. We look at DLNR and Fish and Wildlife Service. The vast, vast, vast majority of all those decision-making positions are filled by people who are not from Hawaiʻi, who don't understand our local values, which are founded in Native Hawaiian values, who don't understand our worldview. They come in with outside ideas of what conservation is and what science is, and they have a tendency to impose those on our communities as if these are things that did not exist in our communities before they showed up. And that leads to contentious relationships between government agencies and local communities. So, we need more people like you getting graduate degrees and finding your ways into these systems and starting to fill the seats of power so that when we talk about these things, we're not talking foreign languages to each other. To me, that's how it's going to change. Because the people already know. It's the people in government who have a real hard time understanding.

Kade: And would you say that education in general is a vital tool in conveying that message?

[David]: Yeah, because our institutional education systems are teaching an American worldview to our kids. It's not that humans are separate from nature and inherently destructive of nature. It's not the way I was taught to see the world. But that's kind of how they're teaching the kids nowadays. So, we need education systems that teach from our worldviews. And there are some schools that do that and some amazing teachers that do that. But as a system, I don't think we're ever close to doing that

Kade: How do existing environmental laws (e.g., Clean Water Act, Endangered Species Act) impact hatchery operations in loko iʻa?

[David]: That's an interesting question. So, I think those are important laws, but there are other ones that are more important in my experience. So, one of them has to do with the rules and regulations of the Army Corps of Engineers and whatever law grants them the authority to do what they want, which is not aligned with fishpond restoration activities. Are you only interested in federal laws or state laws as well? (State laws as well) Yeah. So, our state constitution and the associated water code in Hawaii protects native Hawaiian uses of water. Whether or not the state actually follows its own laws is another question, which is why communities keep suing the state for them to follow their own rules. But using Heʻeia as an example, Heʻeia Stream has about 40% of the water flowing through it today as it did 100 years ago. And that fishpond there at Paepae o Heʻeia was designed and engineered to have all that water. Not all of it is flowing in, but I'm trying to say there's basically 40% of the water flowing through the watershed, you know, using the stream flow as a proxy for the entire watershed water budget. So, that fishpond was designed to have way more than double the water it has, than what it is getting access to now. So, where is that water going? They drilled tunnels and wells, one tunnel and two wells in Heʻeia to supply homes and businesses and military bases with water. So, the last figures I saw just earlier this week, I think, or last week was that the military base at MCBH Marine Corps Air Base Hawaii was taking more than three million gallons of water a day. So, you know, the board of water supply has a diverse system of water distribution, but a lot of that water comes from He‘eia Stream. So, my understanding is that of those three million gallons a day, one million gallons goes to water at the golf course there. You start to think about all the golf courses we have. So, we have the one on Marine Corps Base, which gets a million gallons of water a day. We have another two golf courses in Kaneohe with one in Kailua. And so, all of these golf courses are taking a lot of water every day. So, one of the things, like I was saying earlier, our state laws and constitution embodied in the water code are to protect Hawaiian uses of water, which is growing taro, growing fish, all these kinds of things. One thing that's not constitutionally protected is golfing, watering golf courses. So, that's not a protected water use, but yet we have a system that is protecting that use of water at the expense of traditional customary practices of growing kalo and fish with that water. So, in this case, we have laws that are supportive of these things, but the state isn't following their own laws of being the water commission and board of water supply is not, in my legal opinion, as an ecologist, is not living up to the expectations or the mandates that are articulated in the water code. So, it's mostly between the commission of water resource management, the laws surrounding native Hawaiian water rights in Hawaii that are really important. And that's why I said, like, if we don't get the water back in He‘eia, it doesn't matter how much pua you stock in the pond, it's not going to sustain them because we don't have the water, freshwater inputs and nutrient inputs that it was designed to, required to support all these fish. So, but, you know, for those other laws specifically, the Endangered Species Act, federally, we have state law too, we have a state endangered species list and law. It's chapter 195 D specifically. So, one of the things is that are these areas of indigenous infrastructure being lo'i and loko i’a are also provide habitat for endangered water birds and things like that, which is a good thing, but the way these laws are interpreted quite often will be based on a worldview and assumptions that have concluded without real scientific evidence that humans are bad for these things. So, the best thing for the birds is to get rid of the people, even if the birds are there because of the people. So, it's just like a cat-and-mouse game with the Fish and Wildlife Service and how they interpret the Endangered Species Act and how they view people as a part of that. So, a lot of the science we do tries to show that in cases like this where there are restorations of indigenous infrastructure, it's actually good for the birds and identifying people as a problem will only be counterproductive to recovery efforts for these endangered species.

Kade: Yeah, because I remember from, because I did [an internship] over the summer and the workers at [a nonprofit] were kind of explaining about how a lot of like the endangered birds are going back into those restored areas, and how they suggested to not take any pictures of just because the whole thing with like being close to one another and stuff, and then how they don't want to get the feds to come over and like close and try and shut down the place because of the birds coming back.

[David]: Yeah, I mean we've already got them, Fish and Wildlife Service, to issue another biological opinion. The first one said a 30-meter buffer around the nest. They have since issued a second biological opinion. So, I wouldn't, I would think whoever told you that isn't understanding the current state of the relationship with the Fish and Wildlife Service. But, you know, people get paranoid and people don't trust the government no matter what they say. So, I understand where it comes from.

Kade: Would hatcheries in conjunction with upland restoration ensure consistent fish populations? What about areas where upland restoration is limited/nearly impossible?

[David]: Yeah, well, upland restoration is half the story. Ocean restoration is the other half, and so the way I think about and describe our indigenous aquaculture systems and how you refer to as loko iʻa is that they are systems within systems, and these systems were designed and engineered you know at least the one in Heʻeia 800 years ago, and the inputs both on the mauka side and the makai side were very different and so with the fish pond at Paepae o Heʻeia, you can't just restore the wall and expect the fish to come back. And similarly, I don't think you can restore the wall and just keep stocking it with fish from hatcheries and expect it to work. It wasn't designed to be like that. So, theoretically, the hatchery offsets the missing inputs from the estuary, and still has the makai stuff to do. So, in that sense, I'm talking myself into convincing myself that the hatchery could be the band aid solution on the makai side, but it would only work if there's coupled restoration on the mauka side. But I'll still say that the end game is to have a healthy makai system feeding our fish ponds and healthy mauka systems feeding our fish ponds so they can truly work again.

Kade: What are some long-term solutions that you would suggest regarding getting fish back into the loko iʻa?

[David]: So, on the makai side? Well, let me start, mauka, just really briefly because I can't really talk about things as if they don't exist within the context of everything else. So, you need certain kinds of water, quantity and quality inputting from mauka. If you don't have that right, it doesn't matter what's happening on the makai side. If it doesn't happen, it doesn't matter how much fish you stuff in there from hatcheries. So, the water quality issues need to be addressed. On the makai side, you know, if we had a healthy coral reef ecosystem, then it would be producing the pua, the baby fishes, juvenile fishes that are needed for, that these loko iʻa were designed to enhance, you know, in terms of their population. So, I mean, there's obviously lots of species. The main one we talk about is mullets, striped mullets. So, we'll stay in that zone for now, although to be complete, we should talk about all species. But that one's a really good example because there's different kinds of ʻanae. A really important one in the context of restocking our ponds is ʻanae holo, the one that migrates across the island and spawns the whole way.

In the old days, those things, those ʻanae holo were kapu and protected. It's because you could catch an ʻanae holo and eat a lot today, but you're stealing the food from your grandchildren's mouths in the future. So, we need those ʻanae holo schools to come back. Even if we put a kapu on them, they're not going to come back like before because of the water quality. So, it's all very cyclical. But if we want to have a healthy fishery, we need to be engaged in more pono fisheries management, which includes supporting things like lawai'a pono, which is traditional Hawaiian fishing ethics and values associated with feeding family from the ocean. It takes a shift from the "take as much as you can, as quickly as you can, before somebody else gets it way of thinking", into "we've got to make sure our ocean is fat for our future generations", those kinds of things. That's what needs to happen.

Kade: In light of recent developments within federal funding, how are local restoration efforts being impacted?

[David]: Good question. I think under the Biden administration, there is a big push for the various infrastructure bills of BIL and IRA. There's a lot of support that was coming into Hawaiʻi to restore these systems. I think there was a lot of talk of restoring Mokuʻula in Lahaina. I haven't been following those discussions closely, but that was going to happen with federal money. So, I think, I mean, money always helps, but it's not a make-or-break situation. Especially if you're doing the smaller the scale, the easier it is to do with just a handful of people who really care. So, like, Paepae o Heʻeia, they've been working on their restoration almost 25 years now, and they've never received federal money for the restoration. They, I mean, always had help, but it was not federal help. It was mostly people showing up who were dedicated and willing to get dirty, willing to work hard, willing to break the sweat, and occasionally spill some blood. And there's a lot of communities around Hawaiʻi who have just done it. So, you know, those are more small-scale things, like single-fish ponds or single loʻi complexes. But we were looking at this big infusion of federal funds to take a huge giant leap forward in restoration of these systems, and especially systems that have been so far, or so altered, like Mokuʻula. It's almost, it's pretty hard to imagine how you do a project that big without federal dollars. So, not impossible, but hard.

Kade: I feel like a lot on that note, I feel like community outreach is probably going to play a huge role alongside federal funding.

[David]: Outreach, yeah. I think the bigger thing, from my perspective, is empowerment. There are communities in Hawaiʻi who have never lost a sense of kuleana for their places, and these are the communities that are leading in all these amazing restoration efforts. But reality is, it's the minority of communities in Hawaiʻi. The majority of communities, from what I can see, don't feel like it's their kuleana to take care of their reefs, to take care of the forest. It's like, "Oh, that's the state's job. Somebody else will do it." There aren't enough communities in Hawaiʻi who feel empowered that it's their kuleana to take care of their reefs, to take care of their forest, to take care of their stream. But Hawaiʻi is one of those that feels empowered. Other places, in Kauaʻi, there's Ha'ena, Waipā. In Hawai'i Island, there's Kaʻūpūlehu. So, there's these examples on every island that can be looked to. But yeah, so to me, community empowerment is the bigger thing than outreach. And yeah, just to be clear, I'm not anti-hatchery. I think they're important. I don't think that we should look at them as these important band-aid solutions for now, until a time such that we can get the rest of our systems healthy. And so, to me, that should be a part of the messaging.

APPENDIX 5

Interview Date: 3/10/2025

Interview Location: Zoom

Interviewer: Kade Jacang

Interviewee: [Kevin Kohl]

Kade: How is [your loko iʻa]'s relationship with OI (or other research centers)?

[Kevin]: Yeah, I would say the two main kinds of hatchery and fish research centers we have relationships, I would say aquaculture research facilities, I would say we have relationships with three: OI being one, UH Hilo, PACRAC being two, and then Ānuenue Fisheries Research Center being three. Our relationship with all of them is great. Oceanic Institute (OI), we've been working with them for close to 20 years now. I think it was about 2006, 2007 that we first did fisheries work with some employees that are no longer working there. And it was with finfish, so it was dealing with moi. And then there was a pause for a few years in the 2010s. But then in the late 2010s, we got back together again with the finfish department and did mullet. We got mullet fingerlings several times. So yeah, our relationship is really good. It's good, but the frequency with which we work together is grant related, obviously. But yeah, we have a great working relationship with them. We also did our limu research projects with them in ʻ23, maybe. The one that the next research center that we have the next longest and deepest relationship with is UH Hilo, PACRAC. We have a great relationship with them as well too, mostly with Dr. [Miriam Holmes], and that's shellfish work. So, we've been doing shellfish work with them probably for 16 or 17 years. So, a lot of oysters, clams, different species of oysters. And the oysters have gone back and forth. They've taken oysters from our place and clams from our shoreline back to PACRAC to grow out. And then, they've also raised stock on their side and sent the stock to us. So great relationship, positive relationship, all good. And then lastly, Ānuenue Fisheries in Sand Island. We've been a recipient of their limu overflow in the past few years. And again, relationships are great. Don't work with them nearly as often, but yeah, great people. We have all three research facilities. We have good relationships with the individuals, with the programs that they're running, and yeah, high, high confidence in what they're doing.

Kade: In your experience, how effective have hatcheries been in increasing fish populations in loko i‘a?

[Kevin]: I would say it's been mildly effective, semi-effective. It’s kind of, in some respects, has been extremely effective in that in the years that we're trying to stock pens, and we're raising fish in pens, that was extremely effective and successful because we had a high survival rate because the fish were in pens. They weren't really subject to predation in our larger pond. So those runs of fish were highly successful and effective and we were able to push out fish to the community that was raised in our fish pond and the stock came from OI. We had some challenges at the end, which is why we stopped doing pen culture and we learned pen culture from Oceanic Institute. We put it into production and it worked. It worked well, but we saw for the goals that are towards the end, we had some fish die-offs and we saw for the goals of our organization, we didn't want to use exogenous feed anymore. we didn't want to use pens as much as possible. So in terms of how effective it was later on, it was a little bit more challenging. We got lots of fish from them, but it was challenging on our end, in our pond environment, to maintain survival rates and deal with environmental factors here at the pond: sedimentation, oxygen rates, seasonal shifts, and predation by birds and barracudas and papio. Yeah, so it's not OI's fault. The fish came to us just fine. It's just once we put them in our pond, being that our goals were to minimize using feed and minimize the pen culture, that meant that there were more challenges in the larger pond that we had to deal with.

Kade: I talked with other people and they viewed it as more of a temporary solution because it's only addressing the coastal side with just releasing fish into that environment, while kind of not addressing what's going on in the upland region, because that's one of the main sources of all the nutrients that come into those systems from the rivers. So, I guess, have you worked with OI in terms of trying to figure out how to increase the survival rates?

[Kevin]: Um, I would say we haven't, I'd say no, we haven't really worked with OI to really dig into those factors. I think OI has left it up to us, being the subject matter experts, whatever that means for fishponds, because we're not experts by any stretch in terms of like, how to make our pond perfect, because our pond is not perfect, and we've been doing it for 20 years, and it still has a long way to go. So, we know a lot, but we still have a lot to learn. So, I think OI has rightfully, like kind of stepped to the side when it comes to what we feel is best for the fishpond, but they have lent their expertise and advice, especially when it came to, when we did the pua ‘ama project in 2017 and 2018; we just got a lot of advice from them on parameters that they see in the wild. Like, these are what, these are the areas that the fish thrive in. This is what the water quality looks like. These are the temperatures. So, if as much as possible, you can duplicate that in your pond or get close to that in your pond. So, they gave us advice. They didn't tell us how to do it. They just told us where the fish are, where they see them have success in other captive rearing programs or in the wild. And just tell us, “Here's the information that's out there.” If you didn't know this already, if you can try and get it as close to this as possible or not, just do what we feel is right. And then in regards to like upland stuff, yeah, they, I wouldn't say that's necessarily their kuleana or they're in their wheelhouse. So again, they've, they've allowed us to kind of work with our own partners here in [our loko i‘a] at least on watershed management, and then we relate to it on the fishpond end, but it truly is, fishpond management is a big part of it is watershed management.

Kade: And they're more so providing you with the expertise to help manage those hatchery fish?

[Kevin]: Yeah. And giving us good insight in terms of like, “These are the conditions the fish are being raised in at OI. So just know that they're coming in at like steady 30, 30 PPT, and they're getting like 100, 100% oxygen. And the tanks are 100% clean. And there's very little detritus and stuff on the bottom. The water is UV sterilized.” They'll tell us all these factors ahead of us, bringing them into the near wild. It is a farm system, but we can't control the environmental parameters in the pond very much. We're trying to figure out how to do that. But yeah, so it's been advice and guidance, but not necessarily a how-to manual.

Kade: Have you observed any differences between places that received OI-raised ‘ama‘ama?

[Kevin]: I think I can. I think the only two examples that I can think of are Waikalua, when they put pua ‘ama inside, they built some small, circular net pens. And I think the fish were successful up until a certain amount of time. And then at some point, I don't know if the fish died, or some predators got in, or the fish got out or whatever. But I don't know if those fish were raised to a full juvenile size where they were comfortable being released out into the pond. I kind of feel like they didn't make it that far, which is our experience too, the fish didn't quite make it, or they started dying, and we just released them all and were like, “Hey, you have a better chance out in the pond than stuck inside our pen.” So if I have my facts correct, I think Waikalua's experience was a little bit similar to ours. But then another fish pond that was quite different from ours was Hale o lono fish pond in Keaukaha in Hilo, on the Big Island. And Hale o lono pond was super successful. They received shipments, maybe a couple shipments of pua ‘ama from OI. And they put the fish in their very fresh water ponds, very low salinity, I think 6 to 8 ppt. So, the fish were, the fish were shocked. Maybe not shocked, but I think because they took the salinity down before they were shipped at OI. But from what I heard from those fish pond managers; it was very successful. They had naturally-occurring diatoms growing off the rocks and off the sediment. The fish were getting fat, the fish were growing. There was no chance for predator fish to come in, so they weren't getting eaten. The only challenge they had was, they had an extreme king tide, and then part of their pua pond wall got broken and the fish escaped. So, I think had it not been for that, the fish were on their way to growing from a fingerling out to a good size that they could be released into the larger pond or into the estuary, which they were really looking forward to. But that would have taken a couple years. So, I think the recommendation on their part was they didn't need to change anything in terms of the fish rearing. The infrastructure just needed to be improved or solidified. And then actually, I remember one more pond, Keawanui fishpond on Molokaʻi. They did similar stuff to us as well. They did fish pens, and I think it was moderately successful. It worked okay. Fish were growing and surviving, but they were preyed upon by barracuda that happened to slide in, get into the net pens, as well as ʻaukuʻu. So, I think there have been more instances of, you know, limited success and then ultimate failure for one reason or another.

Kade: It seems that the differences are largely environmental in terms of what factors into whether or not these pua ʻama would survive in the wild or not.

[Kevin]: I would say, yeah, environmental factors would be like low oxygen in terms of our pua pond. The way we first built it, it was really small. So, when we didn't have a whole lot of wind, and the tides weren't moving very much, the fish ended up gasping and they're really having a hard time getting enough oxygen. Our pond was also heavily, we dug it basically out of mud. So, there was some mud left in there. So that probably didn't help with their breathing, living in a really muddy environment. And then other ponds like Keawanui, I think, environmental wise, they built their pond in an area that had some freshwater, but it was also really shallow. So, I think the water got really warm, which affected the fish's metabolism. And because the area they built their pond in was really shallow, they had a lot of bird predation. A lot of ʻaukuʻu hit them. We had some ʻaukuʻu predation, but not that much. I don't know the exact environmental factors at Waikalua. And then at Hale o lono in Keaukaha, their environmental factors were high surf. It was king tides and a high surf that caused their walls to be damaged.

Kade: How do you see the role of hatcheries in relation to the traditional management of loko iʻa?

[Kevin]: I think hatcheries can be an absolute support. They could be a wonderful tool to help both loko iʻa and the wild hatcheries, as long as it's done right. I think both of them can have positive impacts on our stocks of fish. I think for loko iʻa specifically, for whatever the reason is, and not getting into the reasons that wild recruitment is down, there's I'm sure many factors, and that's a whole other can of worms on our wild stocks of fish. But because our wild stocks of fish are down, we don't see the type of recruitment that we read stories about, or we even hear kupuna or people who are still alive in their 70s, 80s, and 90s talk about the fish coming in, dotting the shoreline, looking like rain on the shoreline, swarming the shoreline. We don't see that anymore. And fish ponds were getting a little subset of that, taking a little bit of the cream off the top and going into the fish pond. That's barely happening now, at least at our fish pond. I know it's happening slightly at other ponds. But again, from the stories that we read, stories that we hear, it's a fraction of what it used to be. So, hatcheries can help to fill that gap. And again, like I said, as long as it's done right, I think it's not, depending on who you talk to, hatchery-raised fish can be a little bit of, it gets people excited and passionate, especially when it comes to genetics, and it comes to hatchery-raised fish versus wild-raised fish, and how smart they are. But I think it's being done well in other parts of the world. My mindset was greatly influenced. While I always supported the Oceanic Institute and the work that they were doing, I was greatly influenced last summer when I went to Alaska. And I heard that salmon hatcheries are massive. But the hatcheries that they use to restock their rivers are populated with adults that are fresh every single year. So the fish, and I never knew this, and I guess it makes sense, but I just never thought about it. But the fish come up the stream, some fish get killed and harvested for the eggs and sperm, babies are made, and then they're released into the wild, and those adults are dead. And they're not held in captivity and used for their eggs and sperm year after year after year. And the babies don't stay in the hatchery and are reared up to, so there's not multiple generations staying in a hatchery. It's fresh genetic material every single year. I'm sure there's massive costs involved with hatcheries. And hatcheries got to look for federal monies and state monies, and they got to keep the electricity going, the lights on, and the pumps going. And so it's a high cost. But I think the rewards can also be high. Again, done right, done with community input, sharing their desires for the species of fish, how long the fish stay in the hatcheries, where these fish are being released. I'm not listing all the community concerns, but I think it's workable, like work-through-able. We can work through issues that people may have with it. And then Oceanic Institute has also, and PACRAC and

Hilo, both of them have also proved themselves successful in rearing highly efficient runs of fish. So yeah, I think it's totally possible, and I think at this point, if we're really wanting to talk about being successful in local production, yeah, we have to absolutely consider hatcheries as a tool for feeding people out of fish ponds.

Kade: How might hatcheries fit into a co-management fisheries system?

[Kevin]: Yeah. I don't delve into the fisheries too much. There are other experts out there that talk about it and think about it and have been working in the fisheries management side of it for a lot longer than I have. But personally, I think if we're using hatchery fish to go inside fish ponds, there's always the potential for those fish to escape and go out on the reef. So, I think it's worthwhile to have those conversations, whether the fish are being stocked in a fish pond or in the hatchery, because the fish can escape out of the pond, and they'll become a part of the wild hatchery. And therefore, because I feel like hatcheries can be a useful tool in fish ponds, I feel like hatcheries can be a useful tool for the wild fishery as well. Just because if you're going to put it in one place, it could go in the other place. So, if I'm an advocate for them going in one place, then I'll be an advocate for them going in that other place in the wild. Again, done right. And I think it can be successful. But again, I'm not an expert in terms of fisheries management, so I just think it can be successful. How that actually gets done and how to address all of the community's concerns, what are all the community's concerns, I don't know all of that. I just know what I know. And what I know is limited. I mean, again, just going off the example that I saw in Alaska. I don't know how expensive it is or whatever. But yeah, man, I was drinking the salmon hatchery juice by the time I left there, man. It was so impressive. And the thought process that they had behind it on why they do it a certain way, why they only keep the fish in there for one season. The fish stay there, inside the hatchery, not the nursery, but the fish stay inside the hatchery. It's for a short amount of time. I want to say like 60 days maximum. It might even be less, maybe 45 days to stay in the hatchery, which I think is what OI does. And then as soon as they go out into a nursery, the nursery is out in the water. Like it's not a nursery on the hatchery grounds. It's like they're out in the estuary in net pens and very small, fine mesh net pens. They're out in the estuary. So those fish, and this is important to the salmon life cycle, but those fish, the waters are imprinting on the fish. They're smelling that stream water. They're living in it, right? They're living in that estuary. So even if they stay another three months, six months in that net pen, for 90% of that time, they've been imprinting on that water and surviving in that water with the help of some feed. So, it was just like, man, those fish are eating from those waters right away. So anyways, just all the details of what I saw at the salmon hatchery just gave me hope that we can do something like that here in Hawaii. Maybe one of the challenges is again, funding. In Alaska, there's quite a few hatcheries. So, they can be a little more specific like, "Oh, I only want my river fish, my stock of fish to come from this river. And then I'm only going to release back into the same river." Maybe one of the challenges we have here in Hawaii is the high cost of the hatchery. So, like, OI creating fish for the whole island of Oahu? Maybe that presents some challenges, but are there ways around that? How do we get around that? Do we have specific stock from around the island or does every island have its own hatchery? So, you just have ʻOahu moi, ʻOahu mullet being raised on ʻOahu. Or can we get them out of there and into net pens really quickly? And so, their DNA is, you know, I don't know, whatever. Yeah.

Kade: See, the thing with that is, I don't know, at least from what I remember, because they have like all those runs across the island. So I'm not sure if they necessarily would like to go up that same stream or if they would go up like a different stream to reproduce.

[Kevin]: Yeah. Salmon is super, super different from our own species. And then I think it is worth it to work on hatchery stuff as much as possible in the present. Just looking at DNA around the state in fish. So, I think the state is currently doing that. DAR has a genetic project. And I think that's one of the first steps because that will help to determine, like, giving the hatcheries the right information to then make decisions moving forward. Do we need multiple hatcheries? Or hey, the genetics are pretty similar across the entire state. So, we're actually okay using the hatcheries, sending fish all across one or two hatcheries, providing fish to the whole state. Maybe that's what it takes. We need more information. But again, I think it's totally doable. And I think hatcheries can be a part of the solution.

APPENDIX 6

Aloha! You are being asked to participate in a research study conducted by *Kade Jacang and Bradley (Kai) Fox* from the *School of Ocean, Earth Science, and Technology* at the University of Hawaiʻi. *These results will contribute to Kade Jacang's senior thesis dissertation requirement for the GES major.*

What am I being asked to do?
If you participate in this project, I will meet with you for an interview over Zoom at a time convenient for you.

Taking part in this study is your choice.
Your participation in this project is completely voluntary. You can choose to take part or you can choose not to take part in this study. You also can change your mind at any time. If you stop being in the study, there will be no penalty or loss to you.

Why is this study being done?
The purpose of my project is to assess the use of hatcheries for juvenile recruitment in loko iʻa, and to explore methods of integration or alternatives. I am asking you to participate because of your expertise in aquaculture and/or experience in loko iʻa management.

What will happen if I decide to take part in this study?
The interview will consist of 10-15 open ended questions. It will take 45 minutes to an hour.
The interview questions will include questions like, "How do you think modern hatchery practices can be harmonized with traditional Hawaiian methods of fishpond management?" "What policies or regulations currently govern the use of hatcheries in loko iʻa? Are there any changes you believe should be made?" "What measures are in place to minimize the environmental footprint of hatchery operations, particularly in sensitive ecosystems like loko iʻa?"

Only you and I will be present during the interview. With your permission, I will audio-record the interview so that I can later transcribe the interview and analyze the responses. You will be one of about (5) people I will interview for this study.

What are the risks and benefits of taking part in this study?
I believe there is little risk to you for participating in this research project. You may become stressed or uncomfortable answering any of the interview questions or discussing topics with me during the interview. If you do become stressed or uncomfortable, you can skip the question or take a break. You can also stop the interview or you can withdraw from the project altogether.

There will be no direct benefit to you for participating in this project. The results of this project may help with the future considerations of adaptive measures for loko iʻa as our climate changes.

Results of Research:
Interviews will be sent to participants before writing the final report. The final report will be emailed to participants via link.

Privacy and Confidentiality:
I will keep all study data secure in my personal Google Drive on a password protected computer. Only my University of Hawai'i advisor and I will have access to the information. Other agencies that have legal permission have the right to review research records. The University of Hawai'i Human Studies Program has the right to review research records for this study.

After I run back the interview with participants and write a copy of the interviews with any changes, I will erase or destroy the audio recordings. I will not use your name, or any other personal identifying information that can identify you. I will use pseudonyms (fake names) and report my findings in a way that protects your privacy and confidentiality to the extent allowed by law.

Compensation:
You will receive a $5 gift certificate to The Cookie Corner for your time and effort in participating in this research project.

Future Research Studies:
Identifiers will be removed from your data, and after removal of identifiers, the data may be used for future research studies or distributed to another investigator for future research studies and we will not seek further approval from you for these future studies.

Questions: If you have any questions about this study, please email me at xxxxxxxx@hawaii.edu.You may also contact my advisor, Bradley (Kai) Fox, at xxxxxxxx@hawaii.edu or xxx.xxx.xxxx. You may contact the UH Human Studies Program at 808.956.5007 or uhirb@hawaii.edu to discuss problems, concerns and questions, obtain information, or offer input with an informed individual who is unaffiliated with the specific research protocol. Please visit http://go.hawaii.edu/jRd for more information on your rights as a research participant.

If you agree to participate in this project, please sign and date the following signature page and return it to: Kade Jacang

Keep a copy of the informed consent for your records and reference.

Signature(s) for Consent:

I give permission to join the research project entitled, *Evaluating Hatcheries as a Tool for Fish Recruitment in Loko iʻa*

Please initial next to either “Yes” or “No” to the following:

_____ Yes _____ No I consent to be audio-recorded for this interview.

Name of Participant (Print): ____

Participant’s Signature: ____

Signature of the Person Obtaining Consent: ___________________________________

Date: ____________________________

Mahalo!

APPENDIX 7

Dear [Interviewee's Name],

I hope this message finds you well. My name is Kade Jacang, and I am currently researching the effectiveness of hatcheries as a tool for fish recruitment in loko iʻa. Given your expertise and experience in [interviewee's relevant field, e.g., marine biology, aquaculture, or traditional Hawaiian fishpond management], I would greatly appreciate the opportunity to interview you on this topic.

My goal is to understand how hatcheries can support fish populations within loko iʻa systems, while also considering the balance between traditional practices and modern techniques. Your insights would be invaluable in shedding light on the potential benefits and challenges associated with this approach. If you are available, I would be honored to schedule a conversation at your convenience. I anticipate that the interview would take approximately 30-45 minutes, and we can arrange it over zoom. Please let me know if you would be open to this discussion, and if so, what times would work best for you. I am flexible and willing to accommodate your schedule. Thank you for considering this request. I look forward to the possibility of speaking with you.

Best regards,
Kade Jacang
UH Manoa Student
kjacang@hawaii.edu

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