Ecosystem & Socioeconomic Profile of uku (*Aprion virescens*) in the main Hawaiian Islands

Adam L. Ayers[1,2]

[1] Pacific Islands Fisheries Science Center
National Marine Fisheries Service
1845 Wasp Boulevard
Honolulu, Hawaii 96818

[2] Cooperative Institute for Marine and Atmospheric Research
University of Hawaii
1000 Pope Road
Honolulu, Hawaii 96822

January 2022

NOAA Administrative Report H-22-01
https://doi.org/10.25923/9f2m-4e10

About this report

Pacific Islands Fisheries Science Center administrative reports are issued to promptly disseminate scientific and technical information to marine resource managers, scientists, and the general public. Their contents cover a range of topics, including biological and economic research, stock assessment, trends in fisheries, and other subjects. Administrative reports typically have not been reviewed outside the Center; therefore, they are considered informal publications. The material presented in administrative reports may later be published in the formal scientific literature after more rigorous verification, editing, and peer review.

Other publications are free to cite PIFSC administrative reports as they wish, provided the informal nature of the contents is clearly indicated and proper credit is given to the author(s).

Recommended citation

Ayers AL. 2022. Ecosystem & Socioeconomic Profile of uku (*Aprion virescens*) in the main Hawaiian Islands. Pacific Islands Fisheries Science Center, PIFSC Administrative Report, H-22-01, 62 p. https://doi.org/10.25923/9f2m-4e10

Copies of this report are available from

Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
1845 Wasp Boulevard, Building #176
Honolulu, Hawaii 96818

Or online at

https://repository.library.noaa.gov/

Cover: Photo courtesy of Justin Hospital.

Table of Contents

List of Tables

List of Figures

Executive Summary

In recent years, scientists in Alaska developed a process to create ecosystem and socioeconomic profiles (ESPs) for key fish stocks in the Alaska region. As part of the ESP process, stock assessment scientists, ecologists, oceanographers, and economists worked together to develop and refine key ecosystem and socioeconomic indicators that bridge the gap between climate science, ecosystem-based fisheries management, and next-generation stock assessments. This report is an initial attempt to develop an ESP in the Pacific Islands Region for uku (*Aprion virescens*) in the main Hawaiian Islands. This profile illuminates the social importance of uku, the variation in uku markets across Hawai‘i, how and when fishers target uku and its role as part of a small-boat fishing strategy in Hawai‘i, catch reporting and assessment challenges, and describes ecosystem and socioeconomic research that can improve uku management under a changing climate.

I conducted seven interviews with scientific and regulatory experts at the Pacific Islands Fisheries Science Center and the Pacific Islands Regional Office. These interviews outlined key research gaps and priorities for uku and I used their ideas and input to develop an interview guide to collect data from uku fishers across Hawai‘i. Using this interview guide, and with their informed consent, I conducted 12 unstructured interviews with fishers from O‘ahu, Kaua‘i, Maui, and Hawai‘i Island. I took care to collect perspectives from commercial, non-commercial, and subsistence fishers that use a diversity of different gear types to catch uku around their islands. Their perspectives were analyzed and binned by thematic areas. I also assessed the data availability of various ecosystem and socioeconomic indicators developed by Alaska scientists for uku in the main Hawaiian Islands.

Although uku is not as sought after as ‘ahi and Deep-7 bottomfish in Hawai‘i, uku serves an important social role. Uku can be prepared many different ways, fishers frequently share their catch with others in the community and most commercial fishers keep some uku for themselves because it is so delicious. According to fishers, market demand for uku varies across Hawai‘i. Some pockets within islands experience consistent demand, while other areas may be more reliant on the visitor industry. Most fishers, whether commercially, non-commercially, or subsistence-motivated, will target uku when the weather is good, when they have live bait, or will troll to and from an uku fishing spot. Only a few commercial fishers target uku exclusively, but even then it is seasonal and coincides with summer spawning aggregations. Most fishers stated that catch reporting and assessment processes were flawed without mandatory non-commercial catch reporting and felt that many commercial fishers do not report all the fish they catch, even though nearly every interviewee reported that uku was not overfished. Lastly, a significant amount of data is available for most of the ecosystem and socioeconomic indicators developed by Alaska scientists. After assessing these data sources and conducting interviews with a panel of fishers, there is greater clarity on the types of information that need to be collected to enhance uku stock assessments and improve its management.

In sum, uku is an important fishery in Hawai‘i for both nascent and experienced fishers. Results in this report should help inform future social ecological and economic and management uncertainty analyses conducted as part of Western Pacific Regional Fishery Management Council main Hawaiian Islands uku stock assessment reviews. This initial effort also demonstrates that ecosystem and socioeconomic profiles can also help define stock-specific

research and data needs. Including fisher interviews in this process can help contextualize scientific and management questions and improve understanding of key questions and findings. ESPs conducted on other stocks could be similarly beneficial.

Introduction

NOAA Fisheries recently commissioned an update to their Stock Assessment Improvement Plan titled 'Implementing a Next Generation Stock Assessment Enterprise' (Office of Science and Technology 2018). This technical memorandum outlined ways that NOAA Fisheries can improve stock assessments to make them more compatible with NOAA's Climate Science Strategy (Link et al. 2015) and Ecosystem-Based Fisheries Management (EBFM) Road Map (Denit 2016), two documents that aim to improve federal fisheries management by integrating more biophysical, oceanographic, ecosystem, and socioeconomic data into fisheries management efforts. The Next Generation report includes three major recommendations to support next generation stock assessments: holistic and ecosystem-linked assessments, innovative science for improving stock assessments, and a timely, efficient, and effective stock assessment enterprise (Office of Science and Technology 2018).

To help meet these goals, Alaska Fisheries Science Center, in conjunction with the North Pacific Fishery Management Council, developed ecosystem and socioeconomic profiles (ESPs) for priority groundfish and crab stocks in the Alaska region. These profiles integrated ecosystem and socioeconomic indicators into the stock assessment process. Thus far, profiles have been developed for Saint Mathew blue king crab (Fedewa et al. 2019), sablefish (Shotwell et al. 2018), and walleye pollock (Shotwell et al. 2019). To date, the ESPs for these stocks in the Alaska region are the only ones that NOAA scientists have completed. The collaborative, multidisciplinary ESP process used in Alaska culminated in a research agenda that informed the selection of ecosystem and socioeconomic indicators that feed back into stock assessment. These indicators can be tracked over time and be used as a dashboard for progress on climate and EBFM initiatives in their region. Table 1 provides a full list of ecosystem and socioeconomic parameters considered in Alaska ESPs.

Table 1. Current Alaska ecosystem and socioeconomic indicators.

Parameter	Type
Recruitment Variability	ecosystem
Natural Mortality	ecosystem
Growth Rate	ecosystem
Age at 1st Maturity	ecosystem
Age 50% Maturity	ecosystem
Mean Age	ecosystem
Maximum Age	ecosystem
Length 50% Maturity	ecosystem
Maximum Length	ecosystem
Population Growth Rate	ecosystem
Latitude Range	ecosystem
Depth Range	ecosystem
Temperature Sensitivity	ecosystem
Geographic Concentration	ecosystem
Fecundity	ecosystem

Parameter	Type
Breeding Strategy Index	ecosystem
Spawning Cycle	ecosystem
Spawning Duration	ecosystem
Dispersal ELH	ecosystem
Reproductive Strategy	ecosystem
ELH Survival Settlement	ecosystem
Adult Mobility	ecosystem
Habitat Specificity	ecosystem
Habitat Dependence Index	ecosystem
Prey Specificity	ecosystem
OA Sensitivity	ecosystem
Other Stressors	ecosystem
Mean Trophic Level	ecosystem
Ecosystem value Bottom-Up	ecosystem
Ecosystem Value Top-Down	ecosystem
Commercial Importance	socioeconomic
Constituent Demand	socioeconomic
Non-Catch Value	socioeconomic

In the main Hawaiian Islands (MHI), uku is a socially important and understudied fishery relative to pelagic species such as ‘ahi (yellowfin tuna, *Thunnus albacares*) and Deep-7 bottomfish. Uku landings comprise 23% of the revenue for all archipelagic management unit species in Hawai‘i (does not include pelagic management unit species), which highlights its commercial importance (WPFMC 2019). For more information on commercial landings, revenue, and commercial license holders, see the 2019 Hawai‘i Archipelagic SAFE report (WPFMC 2019). For information on commercial engagement, reliance, and other social indicators for uku, see Hospital and Leong (2021). For the most recent uku stock assessment, see Nadon et al. (2020).

Uku was once the only snapper managed as part of a non-Deep-7 bottomfish management unit species (BMUS) complex but was recently assigned its own annual catch limit (ACL) and the other non-Deep-7 BMUS species were designated as ecosystem component species (WPFMC 2019: 16). The MHI uku fishery is characterized by multiple gear types and fishing motivations, which defy simple socioeconomic characterizations. Likewise, there are questions about uku’s movements, connectivity, and spawning, which make the stock an ideal candidate to develop an initial pilot ESP in the Pacific Islands Region.

The purpose of ESPs are to standardize a process to integrate ecosystem and socioeconomic information into stock assessments and management advice (see Figure 1).

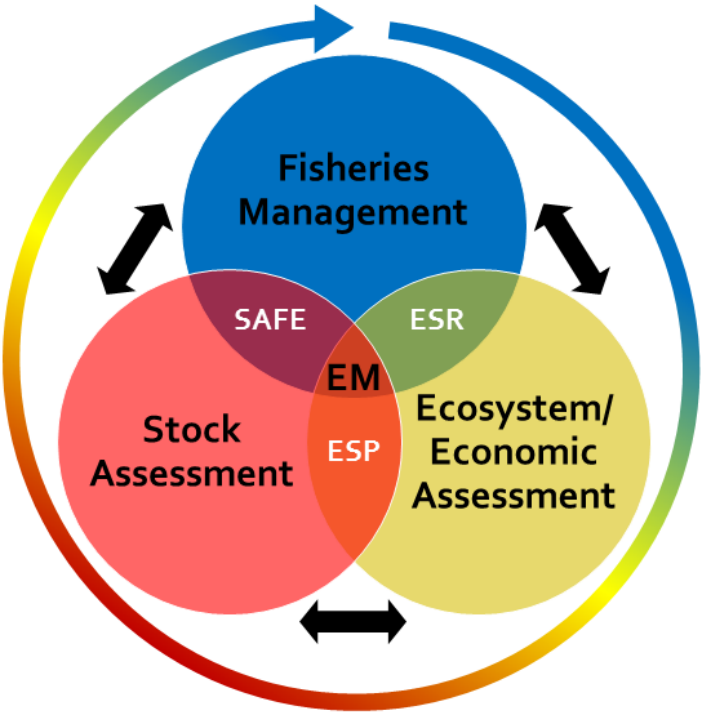

Figure 1. ESP feedback loop. Figure credit: Kalei Shotwell

The purpose of this report is to develop an initial ESP for uku in the main Hawaiian Islands. It is an attempt to better inform and contextualize socioeconomic aspects of future uku stock assessments, determine ecosystem and socioeconomic research gaps for uku, and serve as a model for potential ESPs for other stocks in the Pacific Islands region. The report begins by describing the methods used to collect and analyze data, followed with a presentation of results, and concludes with a discussion of the results in context and a short conclusion.

Fishery Overview

Ecosystem overview

Uku are a reef-associated snapper that can be found in tropical, coastal Indo-Pacific lagoons, channels, and reefs from 31° N and 35° S and 33° E to 134 ° W (Allen 1985; Froese and Pauly 2010). Ukupalu or ‘uku’ are a member of the family Lutjanidae (mean tropic level 4.3 ±0.4 se) and can be found across the Hawaiian Archipelago at depths from 20 to 200 m (Nadon et al. 2020). Uku may live up to 32 years old in Hawai‘i, they reach sexual maturity at age 4, and their reproductive strategy is typified by external dioecism in open waters where eggs are scattered at 20−200 m depths around the main Hawaiian Islands (Allen 1985; Froese and Pauly 2010; Nadon et al. 2020). An analysis of uku habitat completed by Nadon et al. (2020) found that the Maui nui complex (made up of Maui, Moloka‘i, Lāna‘i and Kaho‘olawe) contained a majority of the main Hawaiian Islands uku habitat (58%), followed by Hawai‘i Island (23%), O‘ahu (11%), and Kaua‘i-Ni‘ihau (8%). In Hawai‘i, uku spawning aggregations occur in the late spring early summer, which coincides with peak landings (WPFMC 2019; Nadon et al. 2020).

Gear types and targeting

In Hawai‘i, uku is typically caught using deep-sea handlines, inshore handlines, trolling with bait, and cast netting (WPFMC 2019). Uku is also caught using gear from kayaks, spears/spear guns, and occasionally, shore-based gear. Uku can be caught year-round, but uku landings peak in the late spring or early summer during annual spawning aggregations along the Penguin Banks (Nadon et al. 2020).

Landings and prices from 2003 to 2018

From 2003 to 2018, commercial fishers landed an average of 128,000 lb each year, with a minimum of 75,000 lb in 2018 and a maximum of 164,000 lb in 2007. On average, 349 commercial fishers reported uku landings between 2003 and 2018, with a minimum of 264 fishers in 2006 and a maximum of 418 fishers in 2015 (Hospital and Leong 2021). During that time period, the average number of fishers reporting sales was 285, with a minimum of 214 in 2006 and a maximum of 347 in 2000 (Hospital and Leong 2021). Although the exact number of non-commercial fishers is unknown, Nadon et al. (2020) indicate that non-commercial fishing accounts for approximately 52% of uku landings in the main Hawaiian Islands. From 2003 to 2018, the average price per pound for uku ranged from $3.66 in 2003 to $5.31 in 2018, with a mean of $4.60 (Hospital and Leong 2021).

Key commercial fishing communities (2003−2018)

The highest engaged Hawai‘i communities in terms of the commercial fishing engagement index (FEI) for uku were Honolulu, North Kona, and ‘Ewa census community subdivisions (Hospital and Leong 2021). FEI takes into account pounds landed, revenue, the concentration of commercial fishers reporting landings in a given CCD, and dealers active in the community. Regional quotient is an alternative measure of fishing community involvement that measures the proportion of uku activity in a CCD relative to total activity across Hawai‘i. The three communities that scored the highest in the regional quotient measure for uku in Hawai‘i were North Kona, Honolulu, and ‘Ewa, respectively (Hospital and Leong 2021). The local quotient measures the percentage of a given fishing activity out of all non-longline fishing activity

reported in that community, which can help explain the importance of individual fisheries within a given community. From 2003 to 2018, uku did not comprise more than 20% of landings for the top 7 highest engaged communities (Hospital and Leong 2021). The 3 communities with the highest Local Quotient scores in 2018 were Kahului in Maui, Hanalei in Kaua‘i, and Kīhei on Maui, respectively.

Methods

This research followed a mixed method research design (Tashakkori and Teddlie 2003), combining two sets of qualitative interviews to understand research and data needs along with a review of historical and archival documents to develop a list of potential ecosystem and socioeconomic indicators for the main Hawaiian Islands uku fishery. Below, the different data sources are described followed with a description of data collection and data analysis.

Review of archival documents and previous research

This effort began with a review of recent uku stock assessments (Nadon 2017; Nadon et al. 2020), the annual archipelagic stock assessment and fishery evaluation (SAFE) report for Hawai‘i (WPFMC 2019), the ecosystem and socioeconomic profiles (ESP) completed in Alaska (Shotwell et al. 2018; Fedewa et al. 2019; Shotwell et al. 2019), the NOAA next generation stock assessment report (Office of Science and Technology 2018), and other relevant peer-reviewed scientific research, for example, Meyer et al. (2007); Toonen et al. (2011); Wren et al. (2016); Hospital and Leong (2021). This was conducted to understand; (i) current data availabilities for biophysical, oceanographic, ecological, and socioeconomic information for the Hawai‘i uku fishery, (ii) current stock assessment challenges in terms of ecosystem and socioeconomic data, and (iii) the aspirations by NOAA Fisheries for future stock assessments. This review enabled a more thorough accounting of what research could help contribute to a better understanding ecosystem and socioeconomic variables relevant to future uku stock assessments and the uku fishery overall.

Interviews with scientific and regulatory experts

I conducted unstructured interviews with seven scientific and regulatory experts from NOAA Fisheries Pacific Islands Fisheries Science Center, the Pacific Islands Regional Office, and the Western Pacific Regional Fishery Management Council. Individuals were selected based on their topical and experiential experience with various aspects of the uku fishery. The interviews were brief and focused on two interview topics: how could an ecosystem and socioeconomic profile help fill existing or new research/management needs; and what ecosystem or socioeconomic data is lacking that could be valuable to their work. Their responses were thematically coded using qualitative data analysis methods described by Miles and Huberman (1994) and Creswell (2007), whereby similar themes were binned or grouped together, then counted. Some individuals mentioned more themes than others, but the purpose of the research was to generate ideas, not to draw inferences from individual-level differences.

The information gathered from these two questions helped inform the development of an interview guide used to conduct the unstructured interviews with a panel of uku fishers in the main Hawaiian Islands. The individuals interviewed also helped review and edit iterative drafts of the fisher interview guide used during interviews.

Fisher panel interviews

After completing scientific and regulatory interviews, I began with an initial list of uku fishers suggested by these experts due to their experience in the fishery. Once I completed a few interviews by telephone or by google meet videoconferencing software, I shifted to a purposive, stratified research design (Creswell 2003). Strata were balanced to ensure that I gained some

representation from different islands, different gear types, and different fishing motivations. Following a purposive stratified research design, I interviewed 12 individuals from the 4 most populated Hawaiian Islands, including 6 from Oahu, 2 from Kaua‘i, 2 from Maui, and 2 from Hawai‘i Island. Due to the care taken to interview individuals that fish with different gear types, from different islands, that fish for different reasons (i.e., commercially, part-time commercially, recreationally, and for subsistence), I refer to these individuals as a fisher panel. Citizen panels are frequently used in such diverse situations as market research and jury selection to gather diverse representation or from specific groups (Brown 2006). Since the main Hawaiian Islands uku fishery is so diverse, the interview panel enabled inclusion of voices and perspectives from various segments of the uku fishery.

As mentioned previously, the fisher panel interviews were conducted by the telephone or by Google Meet videoconferencing software. Interviews followed the interview guide (see Appendix A), but I remained open to new conversation threads and topics as they came up during information conversation. I took detailed interview notes during the calls or videoconferences, transcribed responses verbatim, then analyzed the notes using a grounded theory approach (Glaser and Strauss 1967). A grounded theory approach is an iterative thematic qualitative coding process whereby initial strings of text are coded or binned by a specific theme or main idea (this is sometimes called open coding). Later, these coded strings of text or quotes were grouped into more general or abstract themes (this is typically described as thematic coding) that best encapsulate a given phenomenon (Corbin and Strauss 2008). Following this process, fisher panel interview data was frequently tabulated using themes mentioned most frequently, along with interview quotes to demonstrate the applicability of the thematic coding used during analysis.

Review of potential ESP indicators and their applicability for uku in Hawai‘i

I began by reviewing a list of socioeconomic indicators collected, described, and included in Alaska Ecosystem and Socioeconomic profiles. From this list, indicators that were not relevant to the main Hawaiian Islands uku fishery, such as ‘fish roe,’ were excluded. Alaska’s draft list of socioeconomic indicators is longer and includes more variables than were actually used in their assessments, but the draft list provided a good starting point for what socioeconomic variables might be useful in the future in Alaska fisheries as well as for uku in Hawai‘i. For each potentially relevant indicator, I listed the years that the data is available along with a data source and a citation. This process was replicated for Alaska socioeconomic indicators, Alaska ESP indicators, and then concludes with a draft list of potentially relevant ESP indicators for Hawai‘i, based on data availability and potential for use in stock assessment.

Results

The results are divided into two sections: interview data and ecosystem and socioeconomic indicators. The interview data section presents results from scientific and regulatory interviews, followed by findings from fisher panel interviews. The ecosystem and socioeconomic indicators considers Alaska socioeconomic indicators, then Alaska ESP indicators and how they might apply to the main Hawaiian Islands uku fishery. The indicator section concludes with a draft list of ESP indicators for uku in Hawai‘i.

Interview data

Scientific & regulatory interviews

Scientific and regulatory experts frequently cited ‘uku effort/targeting’ and various aspects of ‘Ecosystem research’ as research that would either help improve data availability or data quality for scientific modelling and ecosystem-based fishery management. ‘Market demands/trends,’ and ‘Sociocultural aspects’ were also frequently mentioned. These individuals felt that better understanding of uku market demand and non-market transactions would improve understanding of socioeconomics in the fishery. Others cited better understanding of potential management impacts, coupled ecosystem and socioeconomic research, and in general, socioeconomic research. Others called attention to the need of addressing non-commercial catch, improving data reporting, or general discovery-related research that would help improve scientific understanding and management of uku in Hawai‘i. Table 2 presents thematic responses collected from scientific and regulatory interviews. Overall, these research themes were integrated into the fisher panel interview guide in Appendix A.

Table 2. Suggested ecosystem and socioeconomic profile research themes mentioned by key respondents (n = 7).

Theme/Subtheme	Total mentions (unique mentions)
Uku effort, targeting - Targeting (2) - Shifts (2) - Targeting/Fisheries interactions - Trends - Triggers	7(5)
Ecosystem research - Catch - Environmental factors - uku targeting - uku-opelu relationship - uku-yellowfin tuna relationship - uku targeting and white ulua overfishing - Fisheries interactions	7(5)
Market demand, trends - Demand, trends (2) - Trends in non-market transactions (2) - Market trends	5(4)
Sociocultural aspects (3)	3(3)

Theme/Subtheme	Total mentions (unique mentions)
Management impacts - Impacts of potential fishery closure - Impacts on fishing communities - Impacts of catch limits	3(2)
Socioeconomics - More socioeconomic work - Socioeconomic modeling - Fisher trends	3(2)
Ecosystem and Socioeconomic research - uku-mahimahi relationship - Coupled ecosystem and socioeconomic research	2(2)
Other (2) - Data reporting - General discovery	2(2)
Non-commercial catch (2)	2(1)

Fisher panel interviews

Sociocultural considerations

Socioeconomic and sociocultural aspects

On average, the fishing panel have fished for more than 34 years. Most had fished since they were very young but had spent fewer years fishing for uku (mean = 15.82 years). For these individuals, uku is an important fish for them, but it is rarely a first option. One fisher used an American baseball analogy to put uku fishing in context: "When you go fishing for uku, you're going to get on base. You're not going to hit a home run." In Hawai‘i, a home run might be a trophy ‘ahi [yellowfin tuna, *Thunnus albacares*] or a large catch of culturally significant and economically valuable Deep-7 bottomfish. These catches bring prestige, a nice paycheck when sold, cache when given away to friends or family, and an abundance of likes when posted on social media platforms. Although uku is a delicious eating fish that occasionally sells for as much as $5–7 per pound wholesale, it doesn't bring in the same money that a large ‘ahi or a load of Deep-7 bottomfish might. Nor does it elicit quite the same excitement when given away. But a base hit is still important in baseball and uku is still important for Hawai‘i fishers.

For commercial fishers, selling uku can bring in important income when bottomfishing tapers off or if the Deep-7 Annual Catch Limit (ACL) is met: "uku is such a different fish…it can be in the shallows down to 100 fathoms. The year when they shut down the Bottomfish Deep-7 [when the fishery reached the 2007–2008 TAC on April 16, 2008], that's when I began targeting uku." For commercial fishers, the uku fishery provides an opportunity to diversify their catch and allows them to change their strategy or approach if one species is not biting. The ability to catch uku can make commercial fishers more economically resilient because it allows them to diversify their catch and gives them a different species to target. One fisher mentioned that they often get better prices if they bring in a diversified catch than if they sold just pelagic species or Deep-7 bottomfish alone.

Interview panel data suggest that no one fishes commercially for uku full-time, year-round in Hawai‘i. For commercial fishers on O‘ahu or Maui, uku is a fish they target seasonally during spawning runs in the late spring or early summer when the weather is good. As one fisher explained “summer, I will try to troll for ‘ahi. If the wind is 25 knots, I can’t go for uku when it’s like that. When the wind is light, that’s when people go to the [Penguin] Banks [to target uku during large spawning events].” According to uku fishers on outer islands, uku fishing is different there. Uku can be targeted more frequently year-round on Kaua‘i and Hawai‘i Islands, but is still more of a secondary option: As one fisher explained: “My main focus is bottomfishing in the winter for onaga [long-tail red snapper, *Etelis coruscans*] and opakapaka [pink snapper, *Pristipomoides filamentosus*]. I’m more of a hobby shoreline fisher.”

Uku fishing is similar for non-commercial fishers. If they don’t own a boat, they wait for the call when a friend is going trolling, bottomfishing, or targeting uku. They may own some type of uku gear (see Table 3), but they are only able to target them when they have the opportunity to fish on a boat. Because of this, most of their fishing is not boat- or uku-related: “… [I fish] mostly from shore… shorefishing, but also from the boat, bottomfishing and trolling… I target them [uku] because they’re probably the best fish you can get off the bottom other than the super deep ones [onaga, opakapaka, etc.].”

For individuals that do own boats, selling a portion of their catch from a good day of fishing can help offset expenses associated with fuel, bait, ice, and tackle: “I don’t claim to be a commercial fisherman, I don’t pay my insurance with it, but I do sell to offset my expenses. I just really enjoy it when they’re biting [uku] and I really enjoy eating them.” Even for many of the non-commercial folks, food is a primary motivation:

> [Uku is] …just one of those fish that is good eating and has some value. It’s a fish I like to eat and at that time I was experimenting with a lot of different fishing techniques. Uku was one I hadn’t caught yet, so I wanted to catch them and eat them.

For kayak fishers and spearfishers, catching an uku is a rare and prized fish among the many species they target: “I think I see people targeting them as a trophy and posting photos on social media. Big change to see that. For spearfishermen and kayak fishermen, that’s one of their main targets.” For these fishers, hooking an uku elicits excitement for the fight ahead and anticipation of a delicious meal that can be prepared several different ways. Below, Table 3 presents some summary descriptive information about the uku fishing interview panel.

Table 3. Summary descriptive characteristics of the fishing panel (n = 12).

Characteristics	Count
Island	- O‘ahu (6) - Hawai‘i Island (2) - Maui (2) - Kaua‘i (2)
Mean years fishing [Median] (min, max)	34.83 [34.5] (13, 60)
Mean years uku fishing [Median] (min, max)	15.82 [16] (6, 35)
Predominant gear types used to target uku	- Handline/bottomfish (9) - Kayak (2) - Spear (1)
Types of gear frequently used to target fish other than uku	- Troll (9) - Handline (9) - Shoreline gear (5) - Kayak (3) - Spear (3) - Live bait (2) - Net (1) - Thrownet (1) - Palu ‘ahi (1) - Ika Shibi (1)

Social and cultural significance

Not surprisingly, most fishers reported that the highlight of catching uku is eating it. Seven individuals mentioned how delicious uku is in reference to its social or cultural significance. Seven interviewees also cited how fun uku is to fight as well as its aggressiveness when reeling them in. For commercial fishers, catching uku is a way to make a living, and a way to diversify their income when other fish might not be biting or the market is flooded with other species. Non-commercial fishers fishing from kayaks or diving appreciate uku because it’s a species that they don’t frequently encounter. Other non-commercial fishers cited uku as a trophy fish to bring home from fishing trips. One interviewee described in detail how their fishing practices are interwoven with memories of fishing with their family growing up. But to another, uku was just bycatch, a non-target species when trying to catch Deep-7 bottomfish: “It’s a bycatch. Economically, I don’t see it. No big thing.” Fisher responses are listed in Table 4.

Table 4. Social or cultural significance.

Coding	Quote
Taste (7)	"Well the eating quality is really good. It's one of my favorite fish to eat. I get excited when I see them."
	"Well they taste darn good, I'll say that. Very good tasting fish. Good eating."
	"They taste good."
	"They're just one of the best eating fish that we can catch, that I like to catch."
	"I eat a bunch of it, friends always want it,"
	"The food is probably the highlight of it."
	"Good eating."
Fun to fight (5)	"Fun to fight on the pole, not super into any cultural significance with them, but stoked to hook up with them as opposed to a giant hage [Black triggerfish, *Melichthys niger*]…they're a lot more attractive than a giant hage too."
	"I like catching them. You can catch them on jigs, lures, cut bait, live bait. There's multiple ways to catch them and they're a neat fish."
	"Not spiritually or culturally, the closest thing on the east coast is tilefish. They fight good."
	"They're just a good fun fight to catch."
	"It's kind of a fun way to fish, it's quiet, not noisy."
Pay the bills (3)	"Cultural significance, maybe not so much, nothing to that extent, like red [Deep-7] bottomfish. More for money to pay the bills, have that option, one more tool in the belt [as a small-boat fisher]."
	"I don't fish to give away, I fish to make money and eat. It's a job for me. Uku is a good product and we like to drop off a good product. That's what we do it for, living."
	"It's a means to an end. There's always a good market for it, I can always sell it. The market for uku has never been flooded here to my knowledge."
Aggressiveness (2)	"I had a 14lber come up on me when I was off Hanauma Bay. They're a tough looking fish, they taste great, and I don't get to see them all the time."
	"They're just so aggressive."
Status fish (2)	"So uku, people like to share fishing photos, it has some clout, it's a status fish as well as being good eating. You don't see folks sharing their pictures of manini [convict tang, *Acanthurus triostegus*] on Instagram."
	"All kine. It's a nice trophy to bring home from diving"

Coding	Quote
Rare, Hard to catch (2)	"If you're spearing them, they've got this big bony skull, they'll come in with these gashes on their forehead from the spear if you don't get them right behind the gill plate, they'll get away from you. Especially the bigger ones, they'll take a spear shot and just shake it off. It's kind of hard to describe, they're kind of hard fish to get. They're just sought after, they're a little bit rarer than a papio or a small ulua [giant trevally *Caranx ignobilis*]." "It's not something that I see regularly, not like an uhu or things I can get usually."
Uku bring back family fishing memories	"Uku has a special place for me because it's part of my family. It's memories of my dad and my Uncle that taught me how to fish for it. It's different styles of bait we use, different styles of how to cut your bait and use your bait. I don't know if everybody knows that. We're coming from hundreds of years of knowledge between three people. It started before there was even a GPS. At night I would sit up there with the guy who taught my dad. We knew the depth in fathoms in the dark. Where to anchor the boat. It amazed me as a kid, and still does today. For me it's more of a family history thing. It holds dear for me."
Bycatch	"It's a bycatch. Economically, I don't see it. No big thing."

Culinary preparations

Among the interview panel, the most frequently mentioned uku preparation was fried, either pan-fried or with tempura/panko batter. This preparation was followed by sashimi (6 mentions) and baked/broiled (4 mentions). Others enjoyed eating uku sautéed, steamed, or prepared as poke – diced fish often prepared with sweet onions, sesame oil, soy sauce, and scallions. Poke is a local dish that has become globally popular in recent years. Three fishers highlighted its culinary versatility and one summed it up well: "being fishermen, we have ten different ways and we rotate between them all. Sautéed is probably best. We love it. It's really good." A full list of responses is provided in Table 5.

Table 5. Favorite preparation(s).

Coding	Exemplar quotes
Fried (8)	- Tempura fried (2); - Pan fried with butter garlic salt & pepper; - Fried with butter garlic and veggies; - Panko & egg; - Panko fried; - Fried uku nuggets; - Fried;
Sashimi (6)	- Sashimi (5) - Mostly sashimi
Baked (4)	- Bake or sauté the bigger ones; - Broiled with dynamite sauce; - Fileted and baked; - Baked;
Miscellaneous preparations (3)	- Miso soup with the bones; - Ceviche; - Skin is good descaled;

Coding	Exemplar quotes
Pan seared (3)	- Marinate with honey, ginger and rice wine then simmer in the pan; - Sautéed is probably best; - Pan seared;
Versatility (3)	- Ten different ways; - Versatile; - Versatility;
Steamed (2)	- Steamed Chinese style; - Steamed;
Poke (2)	- Poke (2)
Ciguatera fear (1)	- Ciguatera fear for larger fish

Figure 2. Different uku preparations, clockwise from top left: uku nuggets with lettuce and sweet chili dipping sauce; uku fish head broth; tempura battered fried uku; and uku Jeongol, a Korean-style hot pot. All photos courtesy of Justin Hospital.

Fishing over time

Changes or trends

Half of the interview panel (six fishers) reported that they did not note any trends or changes in the fishery. Of these fishers, many stated their uku fishing was opportunistic, that they did not

have enough uku fishing experience to note any trends. Others mentioned that they found uku at different spots and depths than in the past or that targeting them at deeper depths is preferable to avoid bycatch. One reported difficulty finding live opelu [a preferred bait for uku fishing], while another mentioned a surge of large uku in the 1980s [a spike in the uku catch data was noted in the most recent uku Stock Assessment (Nadon et al. 2020) and abnormally cool ocean temperatures mentioned as a potential driver]. One fisher stated that they were just happy when they catch them. Full quotes from interviewees are presented in Table 6, organized by theme.

Table 6. Changes or trends in fishing over time.

Coding	Quotes
No changes, trends (6)	"I certainly understand catching them a lot better now. Their preferred depth range, type of food they like to eat, the time of day, I know that nighttime is much more productive. I haven't targeted them consistently enough, I'll get into them, and then I'll go back and catch something else. I don't have a good enough baseline to compare. From my friends that catch uku, it seems that there's plenty of them out there, they're not being depleted as far as I can tell." "Not really because it's more opportunistic when I'm targeting them. Not really any trends. Some years I would notice more than others when I was diving on the north shore, but I don't know if that's just a temporal anomaly. Steady trends I haven't noticed any decline or increase like that." "Well, I can't really say that I have, because we haven't caught a ton of them or anything." "Not really to me, because I don't get to go out all the times that I want. Them [uku], or the yellow spots [papa ulua]. But summertime they definitely bite more, bigger." "I don't think so. No I just think some areas people say are fished out and I just say you're in a sandy area. I don't think they're overfished." "No changes."
Different spots, different depths;	"Ka'ena Point used to be really great. Could fish it four times a week back then. But one year they were gone. Could be currents, food. Found them a lot deeper last year, not in the shallows."
Don't catch them consistently;	"I wouldn't claim to be….I'm not a huge catcher of uku consistently. It's more when the weather is good and it's situational. Sometimes when the trolling isn't good, I'll try to catch some uku. I'll go up on the flats and look for them rather than bang my head against the proverbial wall. It usually revolves around the time of year and the weather."
Hard to find live opelu for bait;	"Opelu is the preferred bait for uku. But now you can't get bait. They're drying everything now. Now I use cut bait. That is effective, but you get that shark action."
Happy bycatch;	"So happy and lucky to just catch one. Caught a few from shore and a couple from the boat/kayak. Just a happy bycatch. Just go to areas were there's fish, might be uku/omilu, just drop and hope to catch. I know it can happen, but it's not

Coding	Quotes
	an everyday type of thing."
Surge of large uku in the 1980s;	"In the 1980s we had a surge of uku. Nothing else would bite. One or two or three years at the most. And it wasn't small fish, it was larger size. Some upwards of 20lb. They must have migrated down from Niʻihau, Mau zone [from the Northwestern Hawaiian Islands, now the Papahānaumokuākea Marine National Monument]."
Target them in deeper water to avoid bycatch;	"We try to target it in deeper water, not the shallower water. Because they're so much bycatch. Uku specifically, is seasonal fish. Even though it's caught year round, it's a seasonal fish. We fish uku May–July, end of April, beginning of May–June. For commercial bottomfishers like myself, I don't fish for ʻahi. We fall heavily on uku, it's something that definitely we're going to target and put all our efforts into. And we've been pretty successful."

Unique gear

Fishers also described the gear they used to target uku. Their coded responses and accompanying quotes are presented in Table 6.

Live bait [opelu] and deeper water were most frequently mentioned gear unique to uku fishing, but some fishers use the same gear and techniques used to target Deep-7 bottomfish. Others highlighted the variety of gears and setups fishers can use to catch uku, from shoreline gear, to Damashi rigs (branch lines stemming off a main line with tied flies to attract strikes), handline rigs, and even trolling gear/lures. One fisher fished with just one line and one hook because they felt that shark depredation and bycatch is too great when fishing with multiple baited hooks. Thematically coded quotes are presented in Table 7.

Table 7. Unique fishing gear.

Coding	Quote
Live bait (3)	"If I'm fishing daytime, it's fun to target them with a downrigger. Although I use a downrigger for ono trolling, it's really a different technique. For uku, it's 35 fathom ledge, 15 fathoms off the bottom with a live opelu rig. At night, same technique and reel as opakapaka." "If I had to say one thing I see my peers consistently catching on is live opelu right above the reef. They put a lot more time into the live bait. I usually use dead bait and artificials [baits]. But opelu and akule seem to do a good job. Small goatfish pretty good job as well. I feel opelu can catch anything. They're the snickers bar of the ocean." "Yeah, use like a 5–6' stiff spinner rod with maybe a 6,000–10,000 reel. Usually use a live bait rig with the 6–8' leader to catch them. When you drop the live bait with the long leader they can swim around and they come up."
Deeper water (3)	"More the inclusion of lead. Get it down. You will catch uku on the surface, but incorporating lead into your rig is more productive."

Coding	Quote
	"My dad and the guy that fished with them, and that's all they did was fish shallow water for uku, papio, and weke ula. Since 8–9 years old. Double triple catches since then. We're fishing a mile out from that. They were one hook, one man, one line, no electric reels. Now it's two of us with four hooks and three lines." "Because the Deep-7 was the staple, onaga and opakapaka was a staple. It [uku] would be a bycatch. That was our target, that two main species. Once in a while, we'd catch as spot where the 'paka and the uku would be together. The market would take it, but it wasn't a staple, that would bring a good price."
Variety (2)	"You can catch them any way – trolling, shorecasting, shoreline out to three miles you can catch uku. Old timers used to use handline. Kaua'i guys used to go Northwest [Hawaiian Islands] and get them, they used palu, fished that style. Kaua'i guys still go up in that area Northwest of Ni'ihau and catch them." "We've caught them on a variety of different setups. The first one I caught off of Rabbit Island was with a short kayak fishing pole, with a light medium weight, 10–15-lb test line, with a 3-oz weight and a single circle hook… that's what I use for 'ō'io (bonefish, *Albula glossodonta*) and caught it with a piece of squid. Mokulua islands was using Damashi. The 16 lber I caught off of Rifle Range, I wasn't trolling, I was stopped, and it was probably 25–50' off of the bottom with an opelu on, hooked through the nose and the back. After a couple minutes it started screaming, and I caught a 16lb uku. It had some personal relevance as well. We were actually scattering my dad's ashes that day. We speculated that the cloud of ashes maybe caused the uku to come up. And it was one of the few times that I've actually got the strike on camera."
One hook because bycatch so bad;	"I usually fish only one hook because there's so many sharks. You don't lose the whole rig. It makes is easy for the uku because the uku is one hook versus an Akaka line with 4–5 hooks on it."

Typical trip

Certain themes arose repeatedly during fishing panel interviews. Most frequently mentioned were mixed fishing trips, the weather-dependent nature of uku fishing, and its seasonality. Many boat-based uku fishers will troll on the way to an uku fishing spot, then anchor or drift (with or without sea anchors or engine assistance, i.e., power-drifting) along the bottom structure while targeting piles of uku or bait at their preferred depth ranges. Weather is critical, particularly for targeting uku from kayaks. Weather that is too windy or rough may rule out several fishing spots or fishing trips entirely. Weather can also make the currents too strong to stay on a fishing spot. Others, particularly O'ahu and Maui fishers, mentioned the seasonality of uku fishing and how they primarily target them during spawning events in the late spring and early summer. Other fishers described targeting uku at multiple depth ranges, taking day trips, fishing for uku at a variety of available spots, and fishing for opakapaka often resulted in catching uku.

Figure 3. A fisher displays a nice uku caught on the Penguin Banks during a mixed fishing trip taken from O‘ahu. Photo credit: James Barlow.

In terms of the number of trips taken by interviewees in 2020, which was an unusual year due to the impacts and restrictions of COVID-19, the number of trips ranged from 0 to 68, with a mean of 23 trips. One fisher summed up the strange year: “This last year has been really weird. Not a lot of targeted uku trips. An uku ‘trip’ is often incorporated with another fishing ‘trip’ where they trolled or targeted Deep-7 bottomfish. “This last year has been really weird. Not a lot of targeted uku trips. Many trips I targeted uku but they weren’t an uku targeted trip. Three to four trips a month, fifty?” Another fisher explained that an uku ‘trip’ is often triggered when there are too many sharks at their usual Deep-7 bottomfishing spots:

> “Always carry both [bottomfish and uku rigs] just in case. If sharks are all in the paka [opakapaka] grounds, gear, set-up is the same, gives a lot of options. Also, if you catch 200−300 lb, prices can drop, so it’s better to diversify [and target other species] so prices will remain higher than if you just target only one.”

This quote highlights the value of uku as a fallback plan, as well as a way to diversify the species they sell to earn greater profits. For others, whose commercial fishing trips may be limited due to shore-side employment and family obligations, an uku trip may not be that enticing: “With uku, you’re limited. It’s kind of a last resort kind of thing for me personally. I don’t do it that much now that I’m in Kona.” Full responses are presented in Table 8.

Table 8. Typical fishing trip.

Coding	Quote(s)
Mixed trip (4);	"It would be more in that spawning period in the summer, that quite often coincides with a fuller moon. Good catches leading up to a full moon. Coincides with international grouper/snapper spawning aggregations. I like to have some live bait on board. Get live bait before I go. But also being ready for anything if possible. Not really. I usually have trolling gear. And uku gear so that I have that option as well. The places that I actively fish for uku can range between 5 and 25 miles from where I launch." "Usually if we're going, we'll troll to the Penguin Banks, then change up the gear to bottom for ukus, then troll in. That's usually what we do every time." "It's not that much more effort, if I make a trip up north, Mokulēʻia I'll bring chum, paddle out to the drop off and chum, see if things come in, if not, just do reef diving." "I go to my spots I like to fish, I'll troll there and back. But when I get there I pull everything out of the water and use the floats."
Weather dependent (3);	"Weather is heavily….weather matters for the kayak. Average trip is 5–6 hours because it gets tiring. A lot of time used to get to a spot, there's a lot of factors involved. Open water trip is about 5 hours. Kāneʻohe bay, a little longer because we're a little more sheltered from the weather." "We go out at sunrise, then by noon we're back on shore. Five to seven hours is typical for us to be out. That area we do a lot of trolling. If it's good on the east side, we'll do some bottomfishing around there, trying to get uku, something else that's good. Haven't intentionally caught an uku there. If we're going around Rabbit Island, we do some trolling, but mostly bottomfishing over there. And roughly the same amount of time." "If I'm out of ice, that's a good trip. Banks - 1000lb. But spend more time driving. Eleven hours fishing with a lot of shark predation. Bottomfish, uku, follow the weather. The weather will dictate everything. Moon phases too. Most of the uku caught…it's seasonality too. Other guys that fish on the Banks drift with parachutes [sea anchors]. I'm anchored, but I'm targeting the balls out on the edge on the drop. Weather is number one. Stay away three days before and after new/full moon [because the currents are too strong]. That's 8–12 days cancelled a month because of strong currents. Seasonality too. Always heard that the fish piled up on the Banks [Penguin Banks] after the first big south swell, uku pile up."
Bottomfishing bycatch;	"So it will be one of the fish we catch when I'm going for opakapaka. Will also catch ehu (squirrelfish snapper, *Etelis carbunculus)*, gindai (Brigham's snapper, *Pristipomoides zonatu*), kalekale (Von Siebold's snapper, *Pristipomoides sieboldii*). If you're there for the pakas and you catch uku, you're stoked. I have a couple friends that like to do deep jigging. Might drop some jigs on some of those shallower pinnacles and hopefully catch some uku for dinner. Some 55 fathom pinnacles, 35–50 fathom pinnacles tend to be opelu koʻas. Then you have kāhala, ulua, and a lot of uku. Just above the bottom are opelu schools and jigging is a nice way to catch them. That's a fun way to do it."
Day trips;	"Out of this last year, I probably made six two days trips, caught uku three out of six trips. Last year with the virus, I went just to the buoys, now the buoys are gone. I still had a little bit of the market."

Coding	Quote(s)
Drop bait at various depths;	"Well the way fish for uku is what we call uku bombs. It's an empty Clorox jug with lead and a hook. Some with 25 fathoms written on them and some with 30 fathoms on them. You drop your jugs with live or dead bait in an area around 25 fathoms, then your 30 fathoms in a deeper area. Then you pull them up and whatever you catch, that's how we do it. We rotate between the jugs. You have 9–10 baits in the water instead of just one off your boat."
Variety of spots to target uku;	"We have Lāna'i, outside Moloka'i, outside Hāna, we can target the uku. We go in and target the uku. But that was very few times when the outside was too rough. If we go back to the same place again, I would guess the uku would still be there. But they would move and we would find them at another spot."
Seasonality;	"We only target it during those two to three months. It's generally when they're spawning, that's why they bunch up like that. We fish it here, on Maui, and on the Penguin Banks, which has been the whole thing of uku since day one. That's where all the catch, landings, information came from. There and the middle bank on Kaua'i, that's the two hot spots for uku. During the summer you can't really access onaga, they're not really around. You might get a few paka [opakapaka] in the summertime, that's why we target uku."

Influential factors

Environmental factors

Weather is an important consideration for uku fishing. Good weather allows fishers to target uku at night, which several interviewees said was the best time to catch them. Moon phase was mentioned as another environmental driver of uku fishing, particularly in relation to current, presence of bait or spawning aggregations, and larger tidal swings. One socioeconomic factor mentioned by an uku fisher that crosses over into the ecosystem realm was that uku follows mahimahi (*Coryphaena hippurus*) prices because uku can substitute for mahimahi on restaurant menus. Mahimahi is another white fish with firm light-pink flesh that can be prepared several different ways. One fisher each mentioned how uku fishing is more difficult on Kaua'i than Maui and how the presence of other predators such as kāhala, ulua, and sharks can make catching and landing uku difficult. A list of environmental factors mentioned by fishers and their quotes are listed in Table 9.

Table 9. Environmental factors associated with good/bad fishing.

Coding	Quotes
Weather (5)	"When weather is really good then they'll go for uku. Good fish for markets, for eating. Follows mahimahi prices. Restaurants will tell folks when they can't get mahimahi, they'll substitute uku." (*follows mahimahi prices*) "The day I caught a whole bunch on the Penguin Banks was all nighttime. All my other uku have been daytime. All of my strikes I've had have been in the middle of the day. I think only one time can I remember the weather being a factor. A lot of waves and wind and I caught a small one off Rabbit Island." (*Nighttime*) "It seems like fishermen in their learning progression, a lot of guys will go through an uku phase, they realize they can go at night, get a big haul, make a lot of money, they'll get into it for a few years and target them kind of consistently. Then they'll kind

Coding	Quotes
	of grow out of it, get too busy, then find something else to target. Maybe it is because the yield isn't as great or the time/income ratio isn't as good. Or maybe they need some sleep, whatever it is. It's just something I've noticed. But they keep that knowledge, the spots, how to target them, and even if they don't do it anymore, it's always in their back pocket." (*Nighttime*)
	"Weather for sure. It just makes it easier to stay in the vicinity of where they are. I drift for uku to cover more area. (*Weather*)
	"[Good conditions] I would say as good conditions as you can get for uku is glassy, no wind, mostly you don't want current. [Bad conditions] Basically the opposite of that, windy, choppy, you're probably not bottomfishing. Not really to me, because I don't get to go out all the times that I want. Them or the yellow spots [papa ulua]. But summertime they definitely bite more, bigger." (*No wind, current*)
Moon phase / current (4)	"So not so much presence of any other fish, but in general we seem to have better luck when there's current. When there's no motion, too flat, too calm, we don't seem to catch anything. Seem to have better luck overall when it's cloudy and not sunny weather. Almost every time we've caught uku it's been cloudy and low light conditions, early morning or something like that. If I go out the first day it was calm, I seem to have better luck then." (*Current*)
	"Definitely current. Current is the driver for sure. And then where the current is hitting. When it's hitting topography. Spawning aggregations. Topography and the current are then a driver of the bait. The opelu location a lot of the time is a driver of the uku. All stems from environmental conditions." (*Topography, Opelu*)
	"It's weird, you can go out there the second or third day of the full moon, the fourth day they just don't touch anything. We literally see them on your fishfinder, you catch some, but not like you did the day before. I've tried to dial it in the last 4–5 years and every time you learn something new. Generally start in May, maybe late April, gets really heavy late May into Mid–June, July starts to taper off, then August it's just done. I really only fish uku in one area here. They only congregate one area that I know of." (*Moon phase, seasonality*)
	"Current and moon phase rule the ocean. That's everything, every type of fish. Current and tides. What else is there for the fish?" (*Current and tides*)
Difficult fishing on Kaua'i;	"Maui is so easy. You go out fishing over here [on Kaua'i], it's blowing 25 and there's south swell. Maui is the best place it would appear for bottom, because there's flats. The eggs have a better survival rate, the fish are less stressed. All they got to find is a pile of rocks or a hole, and they've got onaga. I look for them in the same places and they're either there or they're not. But it doesn't seem to work the same over here."
Predators;	"Besides predators, there's certain times when the predators are really bad and I'll lose a lot of them. Sometimes I get to places and the sharks are so bad. Certain places will get infested with ulua and kāhala. Uku seem to be the first ones to the bait. But if there's kāhala and ulua around, they'll keep you busy all day. There's no market for them."

Large aggregations

Respondents also talked about large uku aggregations. Evidence of large uku aggregations was primarily noted by boat-based fishers on the Penguin Banks. But one fisher explained that uku

move a lot and their biomass isn't limited to the Penguin Banks: "They're [uku] constantly moving. Can go to one spot, then not see them there again for 4−5 years. Big Island [uku] biomass is huge." Another fisher reported large uku aggregations when they used to fish around the Northwestern Hawaiian Islands:

> …like tens of thousands. It's crazy. They're spread to the shoreline almost all the way out to almost the 100 fathom curve. We've seen say like Penguin Banks, we see them still following the other fish coming up on the hook. On clear days, that's all you see is uku. The water is 30−50' deep. The school goes from the surface all the way down to the bottom. Paka is targeted and the catch landings are a little more than onaga and it's crazy that uku outdoes that 10−15 times – and it's a big fish!

Seeing large schools of uku is rare for spear fishers, but they do occasionally see them on a dive:

> I've seen schools of small ones, in the 2−3 lb range, but that was super early morning, we weren't chumming, but was a spot that had a lot of other fish. Maybe 15−20, we shot a few then they kind of disappeared. When we're chumming we'll see 5 at a time, not in schools, they're coming to feed, not a huge aggregation.

Another diver reported seeing them often, but not in large schools: "I don't see big schools of them, but we used to dive a lot and they are pretty common. They do come up and bite lures." Seeing large uku aggregations was less likely for fishers that do not target uku on the Penguin Banks or did not fish the Northwestern Hawaiian Islands before it was designated as the Papahānaumokuākea Marine National Monument. As one kayak fisher reported: "We did see a 5−6 lb uku once, it came right up to the kayak on our own. We were bottomfishing and unprepared. It came right up to the kayak."

From the interviews, commercial fishers that spend a lot of time on the water, those that had fished the Northwestern Hawaiian Islands before it was closed, and those that target uku on the Penguin Banks were more likely to have seen large aggregations of uku. But just because fishers don't see large aggregations of uku, it doesn't mean that others don't catch them. It may just mean that they do not target them from boats on the Penguin Banks, a known seasonal spawning aggregation site.

Shift to targeting uku

Since many fishers will bring along different gear types on fishing trips, it is important for fishery managers, stock assessment scientists, and ecosystem scientists to better understand what triggers an uku trip, a shift from one gear type to another, or to move from one fishing spot to the next.

When other types of fishing were poor or good weather – sometimes in combination – were the most frequently mentioned reasons that triggered a switch to targeting uku. One fisher summed it up succinctly: "If the fishing is slow, uku can be a plan B, a backup plan." Although the words 'backup plan' may not make uku fishing sound important, having uku as a backup plan can help ensure that you bring home fish for dinner, have fish to give away to friends and family, to cover expenses for a trip, or pay the bills. Fishers mentioned weather, but more often as a limiting

factor, since it can be difficult to fish for uku and stay on good structure or piles when the wind is strong. The presence of opelu or live bait was another trigger that was mentioned. Many fishers stated that they have a strong likelihood of catching uku if they have live opelu, which is a preferred bait. Others target the same depth range no matter what, and will either catch uku or another species that inhabits that depth. Interviewees also mentioned depredation by sharks, market demand for uku, and seeing uku as triggers for a shift to targeting uku. Table 10 presents coded responses and quotes about what drives or triggers a shift to targeting uku for the interview panel.

Table 10. Drivers that trigger a shift to targeting uku.

Coding	Quote
When other types of fishing are poor (4)	"Often driven by the….if the trolling is poor. And if I notice that the current is doing the right thing in the right place." "When the trolling is slow, uku is quick to set up for. It's shallow, you're fishing in 23–40 fathoms." "I usually have a few just in case, in case I'm having one of those nothings, but honestly I don't bring a lot unless I'm going fishing for uku. If I go out there to do that, that's how I pack my bags. I don't have a very big boat so I don't have a lot of room for storage. Almost everything is on the deck." "If the fishing is slow, uku can be a plan B, a backup plan."
Weather (4)	"Part of it is where we are. Once we get around the channel and around the point. We get a lot of strikes along the cliffs over there from Maunalua Bay to the Rifle Range. Once we get more around the point around the other side, we'll troll down to the blowhole almost, then drift back and bottomfish a little bit. Depends on how much wave action and bounce back there is off of the cliff. Those days we troll. Can get seasick pretty easily if it's rough there." "The wind. If the wind picks up and you're blowing offshore, it's too hard to keep the jugs down deep. If you've got a good size fish on, you'll have to switch. The wind will make you switch to trolling or another method." "Weather dependent."
Presence of bait/opelu (3)	"We've definitely had days when the deep jigging was kind of slow, we'll try to catch some live opelu and target uku if the other fishing is not panning out or not working for some reason. If at the end of the day and I have some live opelu I want to use it, I'll target some uku." "Other than trolling, it kind of goes the same. Find kind of a spot with a lively bottom, catch bait, then slow drift and hope to catch the targeted fish. Then back up to the reef where we started catching and keep going." "In the areas that I do know, if the aggregations of bait are there, then the uku are going to be there. That would be a drive for me for sure."

Coding	Quote
No change (2)	"Only when I go on a boat [with friends] because their knowledge is so insane. When I go by myself, I use the spray and pray technique. I know certain fish at certain depths and topography off of the ground. Try to stay around 100–150' depths." "We fish for uku and yellow spot papio, and of course, onaga. We'll get them on the same line every time. When the uku slows down we switch to targeting only yellow spot papio."
Depredation	Keep moving from pile to pile, find sharks, got to move to another pile.
Market demand	"It's not a really target fish. But once in a while, [a fish buyer] would say we want uku. Our wholesaler would say we want uku. But that was so far and few in between. Only one time they actually asked us to go out and get uku. Other than that it was the Deep 7. Because the Deep 7 was the staple."
Seeing an uku	"The sighting of an uku, that's about it."

Relationship with other species

Fishers frequently mentioned other fish that inhabit similar depth ranges and bottom structure as uku, such as uluas, kāhalas, and various sharks. However, they also mentioned some pelagic species such as ʻahi/yellowfin tuna and mahimahi when dragging bait near a drop off, and Deep-7 species like onaga, opakapaka, and lehi, particularly on the Penguin Banks. A list of species associated with uku is presented in the bulleted list below:

- white ulua (giant trevally, *Caranx ignobilis*),
- kāhala (amberjack, *Seriola dumerili*);
- yellow spot papio/ulua (island jack, *Carangoides orthogrammus*);
- sharks (various)
- kawakawa (mackeral tuna, *Euthynnus affinis*);
- lehi (ironjaw snapper, *Aphareus rutilans*) – along the Penguin Banks;
- onaga (long-tail red snapper, *Etelis coruscans*);
- opakapaka (pink snapper, *Pristipomoides filamentosus*)
- omilu (bluefin trevally, *Caranx melampygus*);
- moana (moana kali/blue goatfish, *Parupeneus cyclostomus*);
- nabeta (blackside razorfish, *Xyrichtys umbrilatus*);
- mahimahi (dolphinfish, *Coryphaena hippurus*)
- ʻahi/yellowfin tuna (*Thunnus albacares*)
- kawaleʻa (heller's barricuda; *Sphyraena helleri*);
- barracuda (great barricuda, *Sphyraena barracuda*);
- dogtooth tuna (white tuna/Hogatsuo, *Gymnosarda unicolor*);

As one non-commercial uku fisher explained that when targeting uku, you encounter "mostly uluas, yellow spots [papios], kāhalas, that's pretty much the only big predators. Or big barracudas when you're going for uku. Sharks too." Another commercial fisher said something similar, that it's all about the spot and the targeted range of depth:

> "Some areas seem to have a lot of kāhala, a lot of ulua, but maybe it's the depth I fish too. I think they comingle in that area pretty heavily. There are areas when I go there, I know what's there. I will throw a couple test floats out, I kind of know what will be in that area."

Interactions

Similar to relationships with other species, interviewees also discussed interactions with other species while targeting uku.

Shark depredation was most frequently mentioned during interviews. Fishers mentioned how sharks will follow them to another fishing spot, or they will leave half a fish on their hook when they get it back to the boat. Others did not seem to think sharks were any worse when targeting uku than fishing for other species. One fisher said the solution is to "reel them up as fast as I can" to prevent depredation. Ulua was also mentioned by two fishers, particularly in terms of catch disposition; they're catching more ulua than ever when targeting uku, and larger ulua are difficult to sell to markets due to ciguatera toxin concerns. One fisher each mentioned monk seals and hage. Full coded responses and quotes are presented in Table 11.

Table 11. Interactions with uku fishing.

Coding	Quote
Sharks (5);	"Kind of hard to tell because you get sharked off kind of a lot and you don't get to see what comes up. Sharks kind of follow us a lot of the time. If you catch a lot in an area the sharks will follow us for a while. The fish to sharks ratio is kind of insane. It more or less ruins your day. On the kayak, it just seems like they follow you at a leisurely pace. I don't think we've had uku bitten off yet, more fish that are energetic. Friends that fish for shibi, the blood in the water gets them sharked off." "Oh yea, Sharks are like the worst ones. I honestly have one spot that they will literally follow the boat. You can run a mile away and within 15 minutes they're already caught up to you again. Completely unfishable. You can't even get a line down. Once they show up, you can't even get a line back up." "If I'm chumming sometimes sharks may come around, but that hasn't happened too often. Not really more often than when I'm targeting other species." "Sometimes a shark will bite half of your uku coming up, but usually not as much as the kāhalas." "Sharks love them. They put out that real deep thumping fighting ability. If I'm actively fishing for uku, I reel them up as fast as I can so that the shark doesn't get it. uku, ulua, shark, current, opelu, topography. Opelu, that's the meat in the sandwich I think."
Ulua (2);	"You catch one uku for every five ulua. Consistently for the past 5–6 years." "We catch uluas too, I've even caught opelu on an uku rig, kala (bluespine unicornfish, *Nasa unicornis*), a variety of things. I think as far as sale of uku, why it's targeted because you have 2–3 very nice neighborhoods past the fish market and a lot of them will stop in and tell the owner they want this or want that. They have the market specifically for uku. Whatever you bring them, they will be able to sell. I think in Kona or other places it may be different, but we have a lot of older rich white people and it's easy to pan sear for them, there is a market for it."

Coding	Quote
Monk seals;	“Monk seals, a lot. Guys are afraid to admit it.”
Hage	“Not so much other than sometimes when you’re bottomfishing you catch hage. No issues with sharks yet when we're doing that kind of fishing.”

Catch and markets

Destination of catch

Interviewees also discussed where their uku catch goes as well as where they believe the rest of the main Hawaiian Islands uku goes after it is caught. Fishers frequently mentioned more than one destination, which is why there are more responses (18) than respondents (12).

There seemed to be consensus that no uku is exported and all of the main Hawaiian Islands uku caught in Hawai‘i, stays in Hawai‘i. Many folks will eat all of their catch or give away to friends or family, and even commercial fishers will keep some to eat because it’s so delicious. For uku that is sold, respondents felt that most of it goes to the fish auction which is then distributed among fish wholesalers and then on to restaurants. There was some belief that at least some uku catch goes directly to restaurants, but it is rare to find it in supermarket coolers. Full responses organized by theme are presented in Table 12.

Table 12. Destination of main Hawaiian Islands catch.

Coding	Exemplar Quote(s)
Subsistence/ Give away (5)	“Never sold it. Either ate it or tossed it back if it was too small.” “All of ours is family and friends. Every single time.” “If I keep a fish, I’m eating it. The only reason I fish is to eat fish. If I catch more than I’m meaning to eat, it’s usually invasives [invasive species] and I’ll give them away.”
Restaurants (4)	“Mostly restaurants. It’s not on the shelf on the Big Save.” “For a while it was popular to use uku and say it was opakapaka, because they assume that tourists can’t tell the difference. Sometimes I’ll order it and have a hunch and will be right. If you took a chunk or paka and a chunk or uku together, the uku is a little more firm whereas the paka is more flaky and delicate. If you steamed them it would probably be the same thing.”
Fish Auction (4)	“Honestly I don’t know. I’ll catch a couple uku, if I had a couple surplus fish, I’ll sell them at the auction block. I know who buys it, but I don’t know where it goes. It could go anywhere. There’s been time when I’ve dropped off 10–20 pieces of uku, and there would be a guy selling 60–80 pieces.” “The big market for uku is the auction block. But it’s like Mahi, when one person catches a lot, the prices go down to nearly nothing. That’s just how it is, part of being a fisherman.”

Coding	Exemplar Quote(s)
Fish markets/ brokers (4)	"Might be hooked up to fish brokers on Maui." "There's always room for uku on the market."
No exports	"Not really any uku exports."

Changes in markets over time

Fishers also discussed how uku markets have changed over time. Some fishers did not sell any of their catch, so they did not have anything to report. Likewise, some did not feel that they had been fishing long enough to comment on market changes.

Fishers seemed to agree less about how uku markets had changed over time. What arose from their comments, however, was the amount of variation that exists across Hawai‘i in terms of market demand for uku. In some areas, such as North Kona/Kawaihae on Hawai‘i island and the north shore of Maui, there appears to be consistent demand for uku. According to fishers in other areas, demand is more uneven based on local preferences and tourist preferences. In some areas, demand remains strong, but has decreased in others. Aggregate demand is low in some areas despite uku's long shelf life, culinary versatility, and low price relative to other sources of locally caught fish such as ‘ahi. According to at least two fishers, some restaurants and fish buyers may be hesitant to purchase larger uku due to ciguatera concerns. Full responses are presented in Table 13, organized by theme.

Table 13. Changes in markets.

Coding	Quote
Greater variation in market demand, price (5)	"It really varies. I've seen anywhere from $3 to $7.50 at the very high end. Like anything right? Mahi, you can get $1.5 or $9–10 a pound. A lot of guys have their local market, a neighborhood, they keep those local connections pretty tight to their chest and I don't blame them." (*price variability*) "Economically I think every island is different. Big Island is not into white meat fish. It's hard to sell bottomfish over there. Maui we have a specifically a white meat market. The tourism we have is different so the demand for the type of fish we have is different. Kona they have ‘ahi and that's generally what people want to eat. Kona they have a lot of hotels, but it doesn't bring the demand for fishermen to go out and catch it. Literally they put a sign on the door and it said we're not taking bottomfish. There's just no demand for it, so they're not going to buy it." (*variation in aggregate demand*) "Not many of the restaurants that I know sell it. I'm sure in another year or two restaurants will promote the product that fell by the wayside. You could get five bucks easy for uku two years ago. They hold really well. They stay in the brine real good. That has a lot of positives still today. Just the eye gets a little cloudy. Holding that color. Keeping it in the Brine you lose the gill color, I don't have an ice maker. With just the right amount of water they don't move and scratch each other too much." (*fewer restaurants selling uku*) "Everything has changed. If you're not a good competent fisherman, you'd better

Coding	Quote
	have money from somewhere else." (*market changes*) "Not personally. Because I never really sold uku. I couldn't tell if there's a change in price. I wasn't following it regularly enough. While I've been fishing I've kind of gathered that uku became a substitute for paka or more desirable in the markets, so along with that an increase in demand, price, and targeting them. At some point between 2005 and 2015, somewhere in there. The other concern is ciguatera. I got a case of cig, I'm pretty sure, from a 17-lb uku on Maui. It was pretty mild, just a couple days of aches and chills. Uku case was 2007, so I haven't had it since then. It's the part of the fish you eat, and how much, but I haven't had a problem with it since. So that might be the case. I'm not sure if the auction checks how deep the uku is caught from, but I think they have known fishers and where they get their fish, so they do screen them I'm sure." (*market changes*)
More awareness of uku, better prices (2)	"When I first started selling them, the price we used to get for them never moved at all. But now it's gotten a lot better for sure. I'd imagine that the prices are probably getting up there with onaga and opakapaka now. People like that whole fish – that seems to be the new craze. They like those smaller ones now." (*better prices for uku*) "More people know about uku than before." (greater awareness of uku)
Only sell opportunistically	"If there's enough, then I'll take it to the market. I'm not going to bust up the ocean for a few more dollars. You have to catch a certain amount to make the expense. Now I don't have to catch too much to make the expense." (*expense fishing only*)

Non-market transactions

Non-market transactions cover sales of uku outside of traditional markets such as stores, restaurants, and fish buyers/wholesales. Consistent with findings from previous studies of post-harvest catch distribution in Hawai‘i and elsewhere across the Pacific (Glazier et al. 2013; Severance et al. 2017), several fishers mentioned the importance of sharing their catch with friends and family. But others highlighted that commercial sales occur on social media or craigslist and much more frequently on the side of the road, perhaps without a commercial license. At least one fisher questioned why DLNR does not enforce the rules regarding commercial licenses and catch reports. One said that they still sell all of their catch to the fish auction. Another mentioned that they see a trend of uku becoming a trophy fish for spear fishers and kayak fishers after having seen evidence on various social media platforms. Fishers detailed their thoughts about any changes to non-market transactions for uku in Table 14, organized by theme.

Table 14. Non-market transactions.

Coding	Quotes
Always share catch (4)	"I don't have social media. People like uku, if catch them, give them away first before bottomfish because they're worth less." "Most of the time I give it away or if the market wants it I sell the species. We always give away first. To kupuna or whatever. For me, it's relaxation, not an economic thing. If I catch 30–40 lb of fish, I'm not going to take it to market. Feed the stomach first, take it to friends and family. Take care of them first. I guess everybody is like that that fishes. It's our culture." "Never seen anyone giving it away on social media. We always share what we catch." "I give away a lot of fish, I give my landlord, neighbor fish all the time I think most of the people I tend to, especially people in big families. For me it's my neighbors or I'll bring one to work."
More social media, roadside sales (3)	"Social media sales you'd see maybe 4–5 guys, now upwards of 30 if the fish are running. Either the Hawai'i Department of Land and National Resources (DLNR) guys are related to them and don't bust them or they're too lazy to do it." "I see a big trend to cutting your own fish and selling it in the neighborhood. Once you've got a neighborhood, a network, you can sell $20 bags. Fish is so expensive in the store, they're happy to buy them from you." "I do see Craigslist, ads for opelu and things like that. I know a lot of people like to do the side of the road now."
Sell everything to the auction	"Everything I sell goes to the auction block. Used to be way easier before Covid. They've changed their hours, now it's like an act of God to take fish down the block now. It's really frustrating."
uku as trophy fish;	I think I see people targeting them as a trophy and posting photos on social media. Big change to see that. For spear fishermen and kayak fishermen that's one of their main targets.

Monitoring, management, and implications

Fishery condition

Fishers had some interesting thoughts on whether or not overfishing occurs for main Hawaiian Islands uku population. Most of the fishers felt that there was not overfishing in main Hawaiian Islands uku populations or that it was difficult to definitively comment without more or better data. Others felt that uku needs monitoring, like the Deep-7 bottomfish fishery or that uku was not more overfished than any other Hawai'i fisheries. One individual observed declines in larger uku along the Kona coast. But another individual felt that the biomass north and northeast of Hawai'i island was very healthy. In terms of answers, one fisher felt that a tagging project could help indicate whether there is connectivity between the Northwestern and main Hawaiian Islands and if so, how much. Greater connectivity could help explain how the main Hawaiian Islands population supports so much catch. Full responses are provided in Table 15.

Table 15. Fishery condition.

Coding	Exemplar Quote(s)
Difficult to answer without more data (3);	"Without further research it's almost impossible to answer that. The auction block keeps selling records. You could get uku data from there for the last 30 years, but to really answer that question, a large scale uku tagging project in the NWHI. I just don't think that the MHI could sustain the population that it does." "They're not enough data to tell you that they're overfished. It's too rough outside Waipio valley and Waimanu is incredible uku fishing but guys are always trolling Ono, There's not enough data to tell personally."
No, highly unlikely (3);	"Yeah anything is possible if all of a sudden it was a really popular fish, but I think it's highly unlikely given current popularity and seems like not a ton of people targeting them aggressively. But I could see a trend if there was a lot of flat water and a lot of people fishing at night. So I think it's unlikely, things would have to change dramatically for it to get overfished. I definitely don't think it's overfished currently." "I don't think it's likely. I know about the latest stock assessment that says they're not overfished. I think we only hit the ACL once, back in 2012. But yeah, given the nature of the fishery, its depth ranges, they're pretty good right now, current pressure, pretty sustainable."
uku needs monitoring (2);	"With uku you've got people on kayaks….If they've got the right baits they can catch them. Even divers. It's definitely a different fishery and we understand that as fisherman. You have to look at it as its own because it's so unique. The recreational side is probably ten times more than the deep seven. In terms of people that can access it and put pressure on it. If you think about Deep 7, uku is going to be up there as well. All of that pressure throughout the fishery, it hasn't gone to a place to where we really have to watch what is going on here." "It feels like they're about as overfished I would consider as everything around. It's kind of hard to tell for me. All of my target species you have to put in so much work for it, it's like a little gold nugget. Just catching anything you got to want it. I catch them from shore, on the boat or kayak, they are around. I don't encounter them enough to tell. All the fish in the islands, there's so much fishing pressure I think they're having a hard time."
Solid decline on Kona side;	"I'm not 100% sure on the science on it. Most of the reef fish have a pretty slow growth rate from what I understand. If those areas get hit really hard, they won't come back. In my lifetime, places that used to be really good, I don't even go to anymore. It's kind of not too good. I'll see them diving, it seems like they will always be there. I don't know if they necessarily come and go. I have a feeling that if they stake out an area, they stay there. There's definitely been a solid decline. I lived in Puako forever. You could catch uku all along there. But between Kawaihae and Manalani, you don't see those big ones anymore, those 25–30 pounders. You're lucky to get them 6 or 10lb. You do see them once in a while, but I remember that the little ones wouldn't even get a chance to get to the bait because the big ones were on it so fast."

Options if the annual catch limit is met

Uku is subject to an annual catch limit (ACL) of 127,205 lb. Thus, the interview panel considered what they would do if they uku ACL was met during the year.

Many fishers said they would just target other species if the uku ACL was met. But commercial fishers felt that it could jeopardize their livelihood because they often target uku when other species are not biting or when market demand is lower for other species. Other fishers said that they would release them if they caught them or would abide by the rules, whatever they are, even if it is unlikely that the state portion of the fishery would be shut down. The state would need to pursue administrative rulemaking that would allow authority to close the state portion (within three miles of the shoreline) of the uku fishery (WPFMC 2020a). Full thematically coded responses and exemplar quotes are presented in Table 16.

Table 16. Options if ACL were met.

Coding	Exemplar quote(s)
Target other species (4);	"Gives less options. Personally wouldn't impact that much if bottomfish didn't close too. Restaurants would suffer. Kaua'i and Big Island hotels and restaurants. One of those years, the BRFA really hurt. If it wasn't for uku, I would have been dead in the water. Wouldn't have been able to make boat payments. If cannot fish for Deep-7, then uku is number two. Same during summer when it's 'ahi season. If everyone is targeting 'ahi, then it's a good time for uku fishing. Last time I caught 1000 lb, I had to split up the drop because I only got $1.80/lb. Asian markets have a hard time selling it. They only take the smaller ones, not the larger ones." "Probably just target other species or troll. That would suck if they did that." "I just do what I do. Go deep, we're looking for 'ahi's more."
Catch and release (2)	"I would fish, I would just let them go. I want there to be tighter restrictions on all fishing on the island. I wish more people were involved. I've seen a lot of different types of people, they want the resources to go and continue through the generations, but there's some people that just don't know. It's frustrating to see people disrespecting the fishery. I wouldn't mind buying a permit to fish every weekend if it would help the resource." "Yeah I'd be bummed for sure because they are a good tasting fish. But if there's scientific evidence that says they need to be preserved or recovered, I'm all about preserving ecosystems. If that were the case, I'd toss it back."

Coding	Exemplar quote(s)
Abide by the rules	"Personally I would abide by the rules. I'm thinking about Alaska and New Zealand, if you get caught with the wrong size fish, too many fish, your boat gets seized. When that goes through the courts, people listen and they watch. Unless you get caught, nothing is going to change. Real fishery management would have to happen before you could do anything like that. And I think the Deep-7 trumps uku. The Hawai'i state fisheries management doesn't make a lot of sense to me. Numbers never get reached and then they raise it. People blame the weather, it was super rough this year, that's why we never reached the quota. What if the fishery really was depleted and you just turned a blind eye to it? That's a Pandora's box type question. I can't see uku really coming to the forefront any time soon but I would welcome more research. I'm not a tree hugger but there's value to conservation. If there was a limit placed on recreational or commercial fishers, I think that would be a good thing. But you have to think about the future, if there wasn't seeding and the fishery isn't declining, how long would it take before you get a new baseline? What is your baseline for uku in the MHI?"
Uku would become a subsistence fishery	"If you lose your job, where you go? You go out to the ocean. Subsistence fishery. We don't play with our food. A lot of times it's subsistence on the economics side. Why they say non-commercial? For Hawai'i, I say it's subsistence."
Question the data	"I know a lot of fishermen have questions about….everyone seems okay with using commercial catch reports and using that data for stock management. It's tricky to get recreational data."
Don't spear uku;	"I fish only recreationally now, so it would just be a matter of passing up uku when I see it. It doesn't affect my income or anything."

Accuracy of catch reporting and stock assessments

Fishers also considered the accuracy of catch reporting and stock assessment processes. Most fishers felt that the current catch reporting and assessment processes were inaccurate, to varying degrees. However, they attributed the inaccuracy to different factors. Several pointed to the lack of mandatory non-commercial catch reporting and felt that the non-commercial catch was much larger than the current numbers suggest. Others felt that how non-commercial data is collected and filtered via the Hawai'i marine recreational fishing survey could have some bias, because the commercial/non-commercial sectors are not so clearly delineated. Further, a significant amount of catch happens at night and no surveys are conducted when those vessels return early in the morning. In terms of commercial reporting, several felt the reporting forms were burdensome and may cause some fishers to not report as frequently. Others felt that the current system "only keep(s) the honest people honest." Only one fisher felt that the current reporting and assessment processes were accurate simply because people want there to be fish for future generations and therefore follow the rules. Their coded responses and quotes are presented in Table 17.

Table 17. Accuracy of catch reporting and assessment processes.

Coding	Quote
Inaccurate (9)	"Everyone can access it and the numbers, we haven't seen…I know the recreational side is really important, a black hole of data we don't have. I wish they would make those guys report." (*non-commercial data*)
	"There's not an easy way for non-commercial. Not without a permit or a license. How are we going to get that with a fish catch? Tried to do that voluntarily. We tried to do that with the federal. You register with the federal government, and you give them a report. But very people did that. It's probably 3–4:1 non-commercial to commercial. Can you imagine the pounds of fish that come out of the ocean unregistered?" (*non-commercial data*)
	"I think the commercial catch reporting is pretty accurate for the folks that choose to report. I don't have any guesses as to what that percent is. Those that catch a lot do report accurately. There's not catch reporting on the non-commercial side. We've had some concerns as to how HMRFS does assess the non-commercial catch because they conduct commercial and non-commercial catches at the same time. Folks may not consider themselves full-time commercial fishers and that my affect the non-commercial data, but I'm not sure how that is filtered out." (*non-commercial data*)
	"I think they only keep the honest people honest. I think that sums it up. The honest people are going to report their catches and the lazy people are not. And that's really difficult from a fishery management perspective. I'm a huge advocate of landings on the DLNR report site. If I pulled 500 lb out of the local population and didn't report it, they would never know. The current reporting protocols just keep the honest people honest." (*commercial reporting issues*)
	"50/50. Like I said, it's hard to do all the paperwork when you fish a lot. I think a lot of guys are filling in numbers really. They don't mean bad by it, but they're not knowledgeable about it really." (*commercial reporting issues*)
	"You know when I was fishing all the time, I paid a little more attention to it. Because I was having to file fish reports all the time. A lot of it didn't equate to me, it wasn't really my style of fishing so it was hard to equate to. But some of the declines, the fishery has changed a lot. Even in my little neck of the woods, it's dwindled quite a bit. I am a little worried about it, but I don't think it's dire. Unlike O'ahu, that always had a boatload of people that fish, it didn't used to be like that. In the past 15–20 years the amount of boats have increased." (*Lack of data*)
	"Very inaccurate. It's probably 1:1 reported/non-reported catch or maybe 1:2. Uku is different than bottomfish because recreational [non-commercial] take is way bigger than bottomfish. Can't standardize CPUE by looking at hooks or rigs because it doesn't factor in skill level, the type of gear, etc. There's kayak, drone, deep water jigging is a new technique that is deadly for uku. Use one opelu on that rig and they will bite it. People are fishing more, doing more outdoor activities, seems to be catching on more and more." (*non-commercial data*)
	"There's no system anymore. I built my years in the system. Paying my excise fee. Doing my reports. If you want good accurate data, you're not going to get it. What is the enforcement arm of it? NOAA? They're not going to spend money. The state is the one taking this on, and they're not doing anything." (*commercial reporting*)

Coding	Quote
	"Commercial, I think probably an underestimate because the way the system is set up. I don't think a lot of guys are going to report fish that they don't sell and uku falls into that category a lot of times. There's extra paperwork. That's just laziness and also if people are worried about overfishing or designation of overfishing TAC. So I think the commercial catch is probably a little under, it's really tough to say how far under. Then recreational, uku is a pretty tough fish to estimate catch for. A lot of catch happens at night, a lot doesn't get sold. A guy that goes out before sunset, comes in at dawn and eats his catch, gives some to his neighbors, that's pretty tough to capture. I don't know if it's over or under recreational estimates. A lot of fishermen I talk to in general think that recreational catch is overestimated from a lot of comments that I've heard." (*commercial and non-commercial data issues*)
Accurate	"I've been in a lot of tournaments where people are catching, competitive friendly fishing. A lot of locals try their best to stick to size limits and catch limits. People trying to educate those around them. Places where a lot of locals fish, they all want to fish for life."
Not sure	"To be honest, I don't follow them at all."

Improving catch reporting and assessment

To improve catch reporting and assessment processes, many fishers suggested the need for better data. Some suggested a non-commercial fishing license program and a mandatory non-commercial catch reporting process would improve data collection. According to one fisher, tagging projects could help get fishers engaged in management processes. Others felt that the primary way to improve the process was to build management capacity by improving compliance with license and reporting requirements, funding fishery management, and improving engagement between scientists, managers, and fishers. Fisher ideas to improve catch reporting and assessment processes, separated by theme, are presented in Table 18.

Table 18. Ideas to improve catch reporting and assessment.

Coding	Quote
Data (5)	"Get a handle on the recreational [non-commercial] take. That is key. But all the lessons learned from Deep-7 bottomfish assessment and standardized CPUE is not, wouldn't stay the same between fishers. Uku is much harder to go through that type of process. Bottomfish is one gear type, but uku is small boat, big boat, spear, shoreline, kayak, fish one-time-a-year guy." (*non-commercial data*) "…if they report, then okay this is how much fish is being caught. But if they don't report and we're still fishing at this and missing this information, there's a lot more fish than we actually caught. If it's blowing 30 knots, we go fishing." (*improve reporting*) "Make it mandatory. If you have a permit or a license. Maybe it don't cost you anything. But how are you going to report your catch? On your honor? I don't know how we're going to do it if the people are not honest. If you're not being honest, you're actually hurting yourself and the industry. DAR – don't use our information against us. How do you get people to cooperate and actually conserve our natural resources? Everybody got to conserve like the old days. The old days they would cut your head off." (*non-*

Coding	Quote
	commercial fishing license)
	"I think that the tagging programs are a really good public engagement tool. I know that it costs money to run those programs but the benefits of getting the public involved, reporting their catch, tracking fish movements, and it's a fun project to get fishermen involved in. Fishing clubs are good for capturing more data. A non-commercial license would be really helpful. Which is insane because we're the only state that doesn't have a non-commercial license." (*non-commercial fishing license, tagging projects*)
	"The hard part is, you do have a lot of recreational people, you really can't track them. It's subsistence fishing so I don't think you can enforce any reporting rules on them unless it's voluntary and people get involved. I don't think that it's as small as a percentage as everybody thinks, and that's nearshore. I still consider uku as part of that. Just for our conversation here, subsistence fishermen catch them a lot too. And spear them. That's a really prized fish to spear. If I come across one, I'm taking it [spearing]. They're an inquisitive fish, you can use flashers and stuff and they'll come right in. That's definitely one you're not going to swim past." (*non-commercial catch data*)
Build management capacity (3)	"I think it really comes down to funding. Funding to employ the people to develop protocols, new rules, and positions, and funding to pay officers to uphold the laws to make a change. I think back to Alaska and NZ and the money they put in to actively manage their fisheries. I don't believe that HI actively manages of their fisheries." (*improve management capacity*)
	"I'd have DLNR go around checking people that are selling fish, for CMLs." (*improve compliance*)
	I think better communication from fishermen and scientists. Stock assessment scientists as far as which catch should be attributed to the commercial sector and which is true non-commercial. We're also looking at recreational bag limits like the deep 7 bottomfish to distinguish which catches are commercial or non-commercial. I think broader communication between fishermen and scientists to explain how their data is being used to ensure compliance and accurate reporting I think that's key. (*better communication & engagement*)

COVID-19 impacts

Fishers also considered how COVID-19 impacted their fishing for uku in 2020. COVID-19 affected commercial and non-commercial fishers, and all gear types in one way or another. Several fishers fished less, with some not fishing at all. Their reasons for fishing less varied from increased family responsibilities, to COVID-19 rules, to working more hours. For commercial uku fishers or part-time commercial uku fishers, the fish auction hours changed so they only accepted fish between 1 am and 5 am, which at the least, was an inconvenience and at most, could cause them to lose a fishing day. Most commercial fishers adapted by increasing community (direct to consumer) sales. Others gave away more fish to take care of friends and family in need during a tough time. Only two fishers reported basically no change between a regular year and 2020. One fisher reported that their uku market remained strong despite closed restaurants and fewer visitor arrivals, perhaps further indicating uku market heterogeneity across Hawai‘i. Their coded responses and quotes, organized by theme, are presented in Table 19.

Table 19. COVID-19 impacts on fishing trips.

Coding	Quote
Fished less (4)	"I almost stopped last year. Barely went out. Only went out a few times. There was a period of time where you either weren't supposed to be out or the launch points were shut down. There was a while where you weren't supposed to be on beaches, or even if we were supposed to be out there, we might get in trouble. So we didn't go then. Safety factor, we were pretty isolated. Went less because of those two factors. It's also more of a factor of COVID-19 making me lazy and used to sitting around at home." (*barely fished*)
	"I didn't fish anywhere near as much because I had my kids at home and I just couldn't break away." (*fished less*)
	"I haven't gone in 2020, because of the pandemic, I didn't go get my CML. I just didn't go." (*did not fish at all*)
	"Well for me, I did less because more people were off work fishing [they worked much more because their business is fishing-related]. My fishing trips are rarely optimal. It might be a holiday and there might be 1000 boats out and I'm just happy to be outside. My fishing is different, all my friends fished significantly more." (*fished less*)
Market changes (4)	"In the beginning, it did, more concerned with taking care of the community. Make 3-4 phone calls and everything sold right there at the harbor. Some folks taking the whole load at a lower price. Guarantee prices fell during COVID. Auction changed drop off times, had to take fish in between 1 and 5 am. When you do that you lose a fishing day too." (*more community sales*, *auction changes*)
	"The numbers never change, but the number of trips changed that we were taking. It's more expensive (more trips) and you're only bringing home what you can sell – not what you can catch. We didn't jack the prices up to make money, what we were really doing was taking care of family and friends. So they were more than happy to buy fish. That's one trip to the store they don't have to make. For a little bit more we would clean it for them. We were fortunate enough to give all those years and when we needed the help, those people came back and supported us. It was good, but I don't want the CPUE to reflect the wrong thing that was going on. We could produce as much as we were, we just couldn't sell it, so we weren't bringing home as much as we could. We make money fishing, but that's not why we fish. We fish because we love to fish. That's the whole thing. It's even more than a job for us, it's what we love, and it's what we do." (*more community sales, gave away more fish*)
	"Yeah sure, certainly. Early on the lockdown I didn't want to bring anybody on my boat. I was fishing by myself, I was definitely fishing less. So that was a change. Fished much less. Also there was no market for fish, restaurants were all closed." (*no market for fish*)
	"No. Only thing is it made us sell more to people, friends, family instead of selling to the fish house. We still did, but we did cut more fish." (*more community sales*)
No change (2)	"Honestly, it didn't change it at all. Except in the beginning you were only allowed two people on a boat, six foot distance, but that only lasted like a month and then they changed it." (*no change*)
	"No, not too much. But it did crush the market with all the restaurants closed, there was definitely a glut. Uku was one of the things they never stopped taking. They'll never stop taking uku. The local market is always solid. There was a guy on O'ahu that used to send me coolers and pay for me to air freight them back full of uku for him. We have all these

Coding	Quote
	resorts here, from Kawaihae that have all these big restaurants. The reason we don't do uku that much because we can't get that much of it. Those big restaurants employ the whole area. If it's slow, people have more time to go fishing, but the demand is less. I think they would kind of work inversely." (*uku market remained strong*)

Something managers/scientists may not know

Fishers also considered one thing managers or scientists may not know about uku. Two fishers brought up non-commercial or recreational data as something scientists or managers may not be aware of, whether it was fairness in terms of a potential sector-based allocation or an increasing trend among non-commercial fishers. Others brought up uku behavior, particularly at night and later in the day, which may improve catchability. Additional issues flagged by fishers included uku's varied appetite, island-level variation in markets and fishing grounds; additional research needed on spawning aggregations and tagging; and also that when they bite, it hurts. Table 20 presents full fisher quotes organized by theme.

Table 20. Something managers or scientists may not know.

Coding	Quote
Non-commercial catch (2)	"The whole thing about the fishing. They may not know how vast the recreational side is. They recreational fishermen probably outnumber the commercial guys 10:1. So you know who they're going to come after, us. All of this uku is being caught, the only people that is going to pay is you. And that's really not fair for us as commercial fishermen. And we gotta pay the price at the end? That's not fair. And that's the whole reason I got involved. And that's the most important thing to get a handle on the recreational catch. It's virtually impossible to find, the data, but don't just judge us. I wish they would get a little stricter with, is recreational." "There's all these little technical things. It's not the hardest type of fishing I've done, it's relatively near shore. Recreational guys can do it relatively easily, it gets a lot of pressure and I've definitely seen things change since I've been in it. It seems to be a trend. But I haven't done a lot of fishing during COVID-19, which did stop a lot of people from fishing."
Uku behavior (2)	"I think scientists probably don't know as much as they could about the night hunting behavior of uku. They seem to be in different depths, feed much more aggressively and gather in larger numbers compared to their daytime behavior." "Not really. I think most managers and scientists know…as a diver things I see diving inform….sometimes I'll notice uku more curious, or less worry in the later afternoon, that evening period. But that's kind of true for a lot of fish species. So there's ways that fishers can target them that can be more successful. There's even like little details, sometimes the uku will be really smart, you'll see them, at least spearfishing you'll see them, in areas there isn't many divers, you'll be more successful. CPUE is not the same across the board. It can change based upon location, the diver, the time of day. So I don't know how much of that actually affects management or the data that goes into management. Just things that I've observed that I don't see being taken into consideration into management."

Coding	Quote
Uku eat everything (2)	"They seem to eat everything. I caught them on the tiniest little fly and a nine inch bait fish and everything in between. They're like leopards and they come in and take advantage of the situation. Seen them come right up to the shoreline when chumming." "Definitely catch them bottomfishing as opposed to any other style. Caught them on a variety of different things, they have a wide appetite."
Island-level variation	"Uku fishing is way different on Oʻahu because of methods and markets than on the other islands. Kauaʻi and Big Island are very different. Kauaʻi is really different. Smaller market, they go up Northwest on big boats, can go pretty much year round, plus getting good price per pound. Kahoʻolawe [now closed to fishing] was good fishing grounds."
Uku research	"A regulatory strategist would not know the areas to focus effort on. They need to get a good handle on where spawning aggregations take place. You can have locational, spatial, and timely closures. So I think scientists need to focus on these spawning aggregation sites, figure out where when and how, then institute situational closures. But if they really cared about the fishery and the local population….and of course the connectivity with the monument, that's the other one."
Hurt when they bite	"When they bite, it hurts. One time it clamped down on my finger and boy that thing hurt."

Ecosystem and socioeconomic indicators

Ecosystem and socioeconomic data can potentially provide better understanding of stock specific fisheries by bringing additional relevant data to stock assessment models to help monitor, understand, and anticipate changes to fisheries. I begin by assessing relevant socioeconomic indicators developed by the ESP team in Alaska and assess their relevance, data availability, and source for the main Hawaiian Islands uku fishery. Following the Alaska socioeconomic indicators, I followed a similar process with Alaska's ecosystem and socioeconomic indicators. This list contains ecosystem indicators, but fewer socioeconomic indicators; it only includes ESP data that was used in their stock-specific models. The section concludes by considering a list of potential ecosystem and socioeconomic indicators for the main Hawaiian Islands uku fishery based on a review of Alaska indicators, interviews, and the most recent uku stock assessment.

Alaska socioeconomic Indicators

Alaska scientists have developed a list of socioeconomic indictors for Alaska fisheries based on their importance for fisheries management. Their data availability and data source(s) are provided in Table 21 in order to assess their potential applicability for the main Hawaiian Islands uku fishery. The socioeconomic indicators in Table 21 represent parameters that are relevant to the fishery and are being tracked, but may not yet be incorporated into modeling efforts.

Much of the data used in Alaska is available for the main Hawaiian Islands uku fishery, with the exception of 'Price by size class' and 'Processing employment.' 'Price by size class' would be difficult to estimate based on a variety of size selectivity and market factors, while estimating 'Processing employment' would likely entail an extrapolation from total seafood industry employment, but would likely be inaccurate or miss fishery-specific details and context.

Table 21. Potential socioeconomic indicators from Alaska and their applicability to the main Hawaiian Islands uku fishery, including data availability and source.

Indicator	Data availability	Source
CPUE by season, gear	1948−2018	Nadon et al 2020
Effort (#vessels, #processors)	2000−2018	WPRFMC 2019, Hospital & Leong 2021;
Bycatch by gear, region	1948−2018	**
Ex-vessel value, revenue share	2000−2018	Hospital and Leong 2021
Ex-vessel price per pound	2000−2018	Hospital and Leong 2021
Price by size class	*	*
Fish condition in the fishery	1948−2018	Nadon et al 2020 Kobe Plot
TAC utilization (percent)	2012−present	2012 when non-Deep 7, otherwise more recent
Processors active in the fishery	2000−2018	Hospital and Leong 2021
Processing employment	**	**
Local, regional quotient	2000−2018	Hospital and Leong 2021

**Data deficient*
***Needs to be defined for application to the fishery.*

Alaska ecosystem and socioeconomic indicators

In addition to socioeconomic indicators, the Alaska Fisheries Science Center also developed a suite of ecosystem and socioeconomic indicators to help test, operationalize, and eventually, help anticipate changes in the fisheries NOAA manages. These variables are presented in Table 22, along with their data availability and data source for the Hawai‘i uku fishery.

Many of the ecosystem and socioeconomic indicators are available for the main Hawaiian Islands uku fishery, with the exception of a handful of five indicators: Habitat Dependence Index, OA (Ocean Acidification) Sensitivity, Other Stressors, Ecosystem Value Bottom-Up, and Ecosystem Value Top-Down. A majority of the variables were integrated into the most recent uku stock assessment (Nadon et al. 2020), and many are available for a pretty lengthy time series (1948–2018). Others were filled in using FishBase (Froese and Pauly 2010). The ‘ecosystem’ category contains a variety of different indicators, including life history and oceanographic parameters, which may not usually be classified as an ‘ecosystem’ indicator in stock assessment. They remain under the ‘ecosystem’ category to maintain fidelity with the Alaska categories.

Table 22. Current ecosystem and socioeconomic indicators used in Alaska and their applicability to the main Hawaiian Islands uku fishery, including data availability and source.

Indicator	Type	Data availability	Source
Recruitment Variability	Ecosystem	1948–2018	Nadon et al 2020
Natural Mortality	Ecosystem	2015–2018	Nadon et al 2020
Growth Rate	Ecosystem	1948–2018	Nadon et al 2020
Age at 1st Maturity	Ecosystem	1948–2018	Nadon et al 2020
Age 50% Maturity	Ecosystem	1948–2018	Nadon et al 2020
Mean Age	Ecosystem	1948–2018	Nadon et al 2020
Maximum Age	Ecosystem	1948–2018	Nadon et al 2020
Length 50% Maturity	Ecosystem	1948–2018	Nadon et al 2020
Maximum Length	Ecosystem	1948–2018	Nadon et al 2020
Population Growth Rate	Ecosystem	1948–2018	Nadon et al 2020
Latitude Range	Ecosystem	35°N – 31°S, 33°E – 134°W	Allen 1985
Depth Range	Ecosystem	1948–2018	Nadon et al 2020
Temperature Sensitivity	Ecosystem	Tropical;	Allen 1985
Geographic Concentration	Ecosystem	1948−2018	Nadon et al 2020
Fecundity	Ecosystem	1948−2018	Nadon et al 2020
Breeding Strategy Index	Ecosystem	**	Meyer et al. 2007
Spawning Cycle	Ecosystem	1948−2018	Nadon et al 2020
Spawning Duration	Ecosystem	1948−2018	Nadon et al 2020
Dispersal ELH	Ecosystem	Annually, May−July	Meyer et al. 2007
Reproductive Strategy	Ecosystem	**	(Allen 1985; Meyer et al. 2007);
ELH Survival Settlement	Ecosystem	1948−2018	Nadon et al 2020
Adult Mobility	Ecosystem	*	Meyer et al. 2007
Habitat Specificity	Ecosystem	1948−2018	Nadon et al 2020

Indicator	Type	Data availability	Source
Habitat Dependence Index	Ecosystem	*	*
Prey Specificity	Ecosystem	1948−2018	Nadon et al 2020
OA Sensitivity	Ecosystem	*	*
Other Stressors	Ecosystem	*	*
Mean Trophic Level	Ecosystem	**	(Froese and Pauly 2010)
Ecosystem Value Bottom-Up	Ecosystem	*	*
Ecosystem Value Top-Down	Ecosystem	*	*
Commercial Importance	Socioeconomic	2020	(Methot 2015)
Constituent Demand	Socioeconomic	2020	(Methot 2015)
Non-Catch Value	Socioeconomic	2020	(Methot 2015)

**Data deficient or needs to be defined for application to the fishery.*

Potential main Hawaiian Islands uku ecosystem and socioeconomic indicators

In addition to the Alaska Socioeconomic Indicators and the Alaska Ecosystem and Socioeconomic Indicators, a list of additional ecosystem and socioeconomic indicators potentially relevant to the Hawai‘i uku fishery is provided in Table 22. Many are related to existing social indicators that were developed to help understand fishing communities and their well-being. Other indicators were included in the recent main Hawaiian Islands uku stock assessment (Nadon et al. 2020) or were analyzed in the Hawai‘i Archipelagic Stock Assessment and Fishery Evaluation report (WPFMC 2019).

Although the list presented in Table 23 is not extensive, it is meant to be a starting point to demonstrate the extent of existing ecosystem and socioeconomic indicators in use as well as the potential of additional indicators that could be integrated into future assessments. Something that stood out was the number of ecosystem variables that were either included in the most recent uku stock assessment, were at least explored, or were considered in the annual Archipelagic SAFE report for Hawai‘i (WPFMC 2019). This indicates efforts have been made to attempt to include extra ecosystem and socioeconomic data in models to better understand fishery changes. Additionally, socioeconomic data on uku that could help improve current estimates of catch per unit effort (CPUE) remain elusive. The number of uku-targeted trips is difficult to estimate given that fishers may troll on their way to and from an uku fishing location as well as the lack of a non-commercial fishing license in Hawai‘i. Thus defining uku-targeted trips may require additional discussions with the fishing community to arrive at an agreed upon definition for what constitutes an uku fishing trip. Nonetheless, the extended time series of commercial landings is a strength and data included in the Multivariate ENSO Index could prove valuable in future assessments. Lastly, if data were available, many additional parameters, such as non-commercial participation, non-commercial trips, and additional socioeconomic parameters such as the

relationship between uku and yellowfin tuna targeting would help better understand effort and targeting in the fishery.

Table 23. Main Hawaiian Islands uku ecosystem and socioeconomic indicators.

Potential Indicator	Type	Data Availability	Source
Sea Surface Temperatures (SSTs)	ecosystem	MEI: 1979–2019[2]	(WPFMC 2019)
Wind speed	ecosystem	2003–2018	Nadon et al 2020 CPUE Standardization,
Pacific Decadal Oscillation (PDO)	ecosystem	MEI: 1979–2019	(WPFMC 2019)
Southern Oscillation Index (SOI)	ecosystem	MEI: 1979–2019	(WPFMC 2019)
Oceanic Nino Index (ONI)	ecosystem	MEI: 1979–2019	(WPFMC 2019)
Surface zonal flow	ecosystem	2002–2012	(WPFMC 2019)
Sea Level Pressure	ecosystem	MEI: 1979–2019	(WPFMC 2019)
Surface Meridional Winds	ecosystem	MEI: 1979–2019	(WPFMC 2019)
Outgoing Longwave Radiation (OLR)	ecosystem	MEI: 1979–2019	(WPFMC 2019)
Day Length	ecosystem	**	**
Depth Strata	ecosystem	20–200 m	Nadon et al 2020
Sea Surface Temperatures (SSTs)	ecosystem	MEI: 1979–2019[2]	(WPFMC 2019)
Fisher Experience	socioeconomic	**	Nadon et al 2020
Price per Pound	socioeconomic	**	Hospital and Leong 2021
Housing	socioeconomic	2010–2018	CSVI online[1]
Labor Force	socioeconomic	2010–2018	CSVI online[1]
Personal Disruption	socioeconomic	2010–2018	CSVI online[1]
Poverty	socioeconomic	2010–2018	CSVI online[1]
Occupational Diversity	socioeconomic	2010–2018	CSVI online[1]
Housing Disruption	socioeconomic	2010–2018	CSVI online[1]
Retiree Migration	socioeconomic	2010–2018	CSVI online[1]
Urban Sprawl	socioeconomic	2010–2018	CSVI online[1]

Potential Indicator	Type	Data Availability	Source
Commercial Fishing Engagement	socioeconomic	2003–2018	Hospital and Leong 2021
Commercial Fishing Reliance	socioeconomic	**	**
Natural Hazards	socioeconomic	2010–2018	CSVI online[1]
Unemployment Rate	socioeconomic	1976–2021	Hawai‘i DBEDT[3]
Uku-targeted Trips	socioeconomic	**	Nadon et al 2020
Commercial Landings	socioeconomic	1948–2018	Nadon et al 2020
Non-commercial Landings	socioeconomic	**, 2013–2018 used in most recent stock asssessment	Nadon et al 2020
Total Landings	socioeconomic	1948–2018	Nadon et al 2020
Revenue per Trip	socioeconomic	**	State of Hawai‘i
Gini Coefficient	socioeconomic	**	State of Hawai‘i
CMLs Reporting Catch	socioeconomic	**	Hospital and Leong 2021
Spatial Distribution of Commercial Trips/Landings	socioeconomic	**	**

Data deficient
*** Needs to be defined for application to the fishery*

[1] https://www.st.nmfs.noaa.gov/data-and-tools/social-indicators/

[2] Multivariate ENSO Index Version 2 (MEI.v2)

[3] https://dbedt.hawaii.gov/economic/unemploymentrate-laborforce/

Discussion

Below I consider some larger themes that emerged during the uku analysis, including its social importance, markets, targeting and diversification as a small-boat fishing strategy, uku reporting and assessment, and future ecosystem and socioeconomic research.

Social importance

Uku is not a beloved global commodity like ‘ahi. “Uku fever” was not mentioned during interviews akin to the “‘ahi fever” Hawai‘i small-boat fishers get when yellowfin tuna make their runs across the main Hawaiian Islands. Likewise, uku is not as culturally important and economically valuable as Deep-7 bottomfish. It tends to lose its pretty blue green hues after being on ice for several days and its bony head and toothy mug are less aesthetically pleasing than Hawai‘i’s other beloved deep water ‘redfish,’ opakapaka and onaga. Despite its lower-rung status in Hawai‘i, fishers reported uku is sometimes substituted for opakapaka in restaurants and hotels and its price often tracks with mahimahi.

Uku plays an important role for both nascent and expert fishers, for subsistence, and at times it is valuable commercially. Even commercial fishers reported that they frequently gave away uku to family, friends, and the community. Uku can be prepared many different ways, from raw preparations such as sashimi, poke, and ceviche, and can also be cooked several ways, including baked, fried, steamed, and sautéed. For commercial and non-commercial fishers alike, uku was described as a ‘gateway fish.’ In other words, a fish that is relatively easy to catch, a challenge to reel in, and delicious to eat – one that can get them “hooked” on fishing for life. Often these fishers will progress to trolling for pelagic species or begin a long journey to proficiency as a Deep-7 bottomfisher. However, they will continue to fish for uku for fun, as a fallback to salvage a trip when other species are not biting, or they will continue to target them seasonally during large spawning aggregations. Uku fishing can pique a nascent fisher’s interest and can lead to a lifetime of deep-sea fishing trips, friendships, delicious meals, memories, and maybe even some income.

Markets

The consensus among interviewees seems to be that nearly all of the uku catch stays in Hawai‘i. Despite its culinary versatility and long shelf life, commercial and part-time commercial fishers reported that market demand is uneven across the main Hawaiian Islands. Auction (wholesale) prices for uku can vary between $3 and $7 a pound based on supply and demand. One fisher reported this is partially related to yield. The reported yield on an uku is about 40%, which is lower than that of a small ‘ahi, whose yield is around 60%. The lower yield, its lesser cultural significance, and lack of ‘brand awareness’ among visiting tourists likely create downward pressure on market prices for uku.

Yet, there are pockets around Hawai‘i, such as areas on Maui, Kaua‘i, and Hawai‘i islands where uku demand remains strong. Commercial uku fishers on these islands sell directly to fish markets and restaurants and typically earn on the higher end of average prices for their catch. As described by these fishers, there is either localized demand for whole uku at markets or greater brand awareness and appreciation for it in restaurants or hotels. Although market prices for uku may be uneven across Hawai‘i, uku is a species that is more readily caught on the Penguin Banks

(due to large spawning aggregations) during the summer months after the demand for Deep-7 bottomfish peaks during the wintertime. This allows commercial fishers a period of time to target uku when demand may be lower for Deep-7 bottomfish, thus buoying them economically during what would otherwise be a slower time of the year.

Targeting and diversification as a small boat fishing strategy

In terms of uku targeting, interviewees reported that pure uku targeted trips were relatively rare. Only the best commercial uku fishers will target uku – and only uku – on fishing trips. And these trips are typically seasonal for O‘ahu and Maui fishers due to their proximity to the Penguin Banks. Most uku fishers, whether commercially, non-commercially, recreationally, or subsistence-motivated, reported that they frequently target other species or employ different gear types on an uku ‘trip.’ For example, a fisher may troll on the way to and from an uku spot to try to catch some pelagic species. Or they may change the depths and bait on their Deep-7 handline gear to target uku if Deep-7 bottomfish are not biting or depredation at those depths is particularly bad. Further, many non-commercial and subsistence fishers target depth ranges and habitats where uku can be found and that are also inhabited by other species. These factors demonstrate the importance of diversification as a fishing strategy for Hawai‘i small boat fishing and the importance of uku as a part of an overall small-boat fishing portfolio. Analyzing CPUE trends across different species and their relationship to uku CPUE could help better understand the role of diversification as well as socioeconomic and ecosystem triggers for uku targeting.

Research in other small-scale fisheries have found that diversification as a fishing strategy can increase adaptive capacity of small-scale fishers by giving them additional options under varying social-ecological conditions and by providing them an opportunity to specialize when necessary (Finkbeiner 2015). This was something mentioned by a few commercial fishers in this research. Diversification has been mentioned as an important strategy by other researchers who also raised other important management issues, such as potential regulatory burden and barriers to entry in certain fisheries (Kasperski and Holland 2013). Others described the difficulty of managing social-ecological dynamics as more fishers diversify (Yletyinen et al. 2018). If anything, diversification in Hawai‘i small-boat fisheries strengthens the case for ecosystem-based fisheries management while allowing fishers to be more resilient socially and economically under changing environmental conditions expected to coincide with global climate change.

Reporting and assessment

A majority of interviewees felt that either the catch reporting and assessment processes were inaccurate. This was primarily due to two reasons: lack of non-commercial catch reporting and underreporting of commercial catch. Although non-commercial catch data as well as other data sources, such as diver surveys, were included in the most recent uku benchmark assessment, fishers still questioned non-commercial data because it is not collected via mandatory catch reports as it is for the commercial uku fishery in Hawai‘i. Likewise, some fishers shared a perception that some commercial fishers do not report their catch or underreport by not reporting what they catch and keep or give away. As a solution, some fishers felt that better compliance with catch reporting was necessary, perhaps instituting mandatory reporting for non-commercial fishers. Several initiatives have attempted to address this but none have been successful to date (CI-Hawai‘i and WPFMC 2016; TuckerWilliams et al. 2018). Others felt that the state must do a better job monitoring roadside and social media sales. Despite a perception that reporting and

assessment processes were inaccurate, nearly all interviewees felt that the main Hawaiian Islands uku population levels were stable. Only one interviewee reported that they witnessed declines in larger size classes of uku in North Kona and Kawaihae.

Another issue with uku reporting and assessment is the blurring of fishing motivations. Commercial fishers mentioned that they frequently give away uku to the community. Part-time commercial uku fishers may sell to recoup some of their expenses (frequently referred to as 'expense fishing') or the might only sell if they prices are good. Others with commercial licenses reported that they will keep uku if the prices are too low because they place a high value on the fish. The blurring of commercial and non-commercial motivations in this fishery could seem to complicate clear commercial and non-commercial sectors for ACLs, a management issue that has been raised in recent years (WPFMC 2020a, 2020b). Sector-based allocations have led to conflict in other U.S. fisheries (Goodyear 2007; Brewer 2011; Abbott 2015), so any potential allocation processes in the future should take care to consider social and economic impacts as well as potential conflicts they might cause.

Future ecosystem and socioeconomic research

A significant amount of ESP research has been conducted in Alaska in recent years. This research has generated a list of important ESP indicators that can be tracked over time to improve the management of specific fish stocks. When examining their applicability to the main Hawaiian Islands uku fishery, data is already available for many of these indicators. And many of the indicators are already used in stock assessment or were tested during assessments to determine if they affected model results. Even if they were not included in models, several of these variables such as the Multivariate ENSO index are monitored in the annual Hawai‘i Archipelagic SAFE report. Existing data could help facilitate additional modelling and ecosystem assessments for uku and other species. However, several indicators are missing data, which would facilitate improved modelling and analysis, including the following: uku Targeted Trips, Adult Mobility in the main Hawaiian Islands, Habitat Dependence Index, Ocean Acidification Sensitivity, Breeding Strategy Index, Bycatch by Gear, and Processing Employment.

As mentioned above, fisher-reported data could improve socioeconomic data and further refine 'uku Targeted Trips.' Similarly, self-reporting could include information about bycatch using different gear types. Such improved data could better inform CPUE and bycatch estimates. Processing employment could likely be estimated for uku as a proportion of total processing employment but would not include processing associated with sales via roadside or social media that are not currently captured through dealer reporting. Tagging projects would help inform Adult Mobility in the main Hawaiian Islands. Although tagging projects in the NWHI have demonstrated the mobility and spawning habits of uku (Meyer et al. 2007) and modelling efforts have indicated currents and connectivity for fish species in the main Hawaiian Islands (Toonen et al. 2011; Wren et al. 2016), sonic tagging would answer some important questions regarding uku movements, particularly during spawning. Additional fisheries independent data collection efforts could indicate abundance and habitat dependence for uku using similar technology (cameras deployed at depth) and sampling methods employed for bottomfish in Hawai‘i (Ault et al. 2018; Nadon et al. 2020; Richards 2020).

Conclusion

This report represents an initial attempt at characterizing uku in the main Hawaiian Islands though an ecosystem and socioeconomic profile. By conducting interviews with scientific and regulatory experts, we identified ecosystem and socioeconomic research gaps and key interview topics to discuss with a panel of uku fishers across Hawai‘i. Later, interviews with these fishers provided valuable commercial, non-commercial, and subsistence perspectives about uku’s social importance, markets, its role in an overall small-boat fishing portfolio, and catch reporting and assessment challenges as they see them from the water. Results of a review of data sources and data availability for ecosystem and socioeconomic indicators previously developed by scientists at the Alaska Fisheries Science Center indicated that data is available for these indicators, many from a long time series. Combining these data with interviews helped indicate data gaps for this important fishery and should help clarify questions for both researchers and managers in future years.

Acknowledgements

I would like to thank Justin Hospital for his thoughtful comments and assistance throughout the research process. I would also like to thank all of the interviewees that shared their time and thoughts about uku in Hawai‘i.

Literature Cited

Abbott JK. 2015. Fighting Over a Red Herring: The Role of Economics in Recreational-Commercial Allocation Disputes. Marine Resource Economics. 30(1):1–20. doi:10.1086/679464.

Allen GR. 1985. FAO Species Catalogue. Vol. 6. Snappers of the world. An annotated and illustrated catalogue of lutjanid species known to date. Rome: FAO. [accessed 2021 Jul 20]. http://www.fao.org/3/ac481e/ac481e00.htm.

Ault JS, Smith SG, Richards BL, Yau AJ, Langseth BJ, O'Malley JM, Boggs CH, Seki MP, DiNardo GT. 2018. Towards fishery-independent biomass estimation for Hawaiian Islands deepwater snappers. Fisheries Research. 208:321–328. doi:10.1016/j.fishres.2018.08.012.

Brewer JF. 2011. Paper Fish and Policy Conflict. Ecology and Society. 16(1). [accessed 2021 Aug 27]. http://www.jstor.org/stable/26268832.

Brown MB. 2006. Survey Article: Citizen Panels and the Concept of Representation*. Journal of Political Philosophy. 14(2):203–225. doi:10.1111/j.1467-9760.2006.00245.x.

CI-Hawai‘i, WPFMC. 2016. Feasibility of a Non-Commercial Marine Fishing Registry, Permit, or License System in Hawai‘i. [accessed 2020 Nov 6]. https://dlnr.hawaii.gov/dar/files/2016/12/NCMF_final_report.pdf.

Corbin JM, Strauss AL. 2008. Basics of qualitative research: techniques and procedures for developing grounded theory. SAGE.

Creswell JW. 2003. Research Design Qualitative, Quantitative, and Mixed Methods Approaches. Second. Thousand Oaks, CA: SAGE Publications.

Creswell JW. 2007. Qualitative inquiry and research design: Choosing Among Five Approaches. 2nd ed. Sage Publications, Inc.

Denit K. 2016. NOAA Fisheries Ecosystem-Based Fisheries Management Road Map. Silver Spring, MD: National Marine Fisheries Service, NOAA Report No.: 01-120– 01. [accessed 2021 Jul 30]. file:///C:/Users/Adam.Ayers/Downloads/01-120-01.pdf.

Fedewa E, Garber-Yonts B, Shotwell SK, Palof K. 2019. Ecosystem and Socioeconomic Profile of the Saint Matthew Blue King Crab stock in the Bering Sea. In: Saint Mathew Island Blue King Crab Stock Assessment 2019. Juneau, Alaska: Alaska Fisheries Science Center. (C4 SMBKC SAFE). p. 99–113.

Finkbeiner EM. 2015. The role of diversification in dynamic small-scale fisheries: Lessons from Baja California Sur, Mexico. Global Environmental Change. 32:139–152. doi:10.1016/j.gloenvcha.2015.03.009.

Froese R, Pauly D, editors. 2010. FishBase 2000: concepts, design and data sources. Los Banos, Laguna, Philippines: ICLARM. [accessed 2021 Jul 20]. https://www.fishbase.se/summary/Aprion-virescens.html.

Glaser B, Strauss A. 1967. The discovery of grounded theory. 1967. Weidenfield & Nicolson, London.

Glazier E, Carothers C, Milne N, Iwamoto M. 2013. Seafood and Society on O'ahu in the Main Hawaiian Islands. Pacific Science. 67(3):345–359. doi:10.2984/67.3.4.

Goodyear CP. 2007. Recreational Catch and Release: Resource Allocation between Commercial and Recreational Fishermen. null. 27(4):1189–1194. doi:10.1577/M06-210.1.

Hospital J, Leong K. 2021. Community Participation in Hawai'i Commercial Fisheries. United States. National Marine Fisheries Service., Pacific Islands Fisheries Science Center (U.S.), editors. doi:10.25923/p4aj-k323. https://repository.library.noaa.gov/view/noaa/30731.

Kasperski S, Holland DS. 2013. Income diversification and risk for fishermen. Proceedings of the National Academy of Sciences. 110(6):2076–2081. doi:10.1073/pnas.1212278110.

Link JS, Griffis R, Busch S. 2015. NOAA Fisheries Climate Science Strategy. U.S. Dept. of Commerce NOAA Technical Memorandum Report No.: NMFS-F/SPO-155. [accessed 2017 May 19]. http://www.eswr.com/docs/science/noaa-climate-strategy.pdf.

Methot RD. 2015. Prioritizing fish stock assessments. Silver Spring, MD: U.S. Department of Commerce Report No.: NMFS-F/SPO-152. [accessed 2021 Aug 26]. https://www.st.nmfs.noaa.gov/Assets/stock/documents/PrioritizingFishStockAssessments_FinalWeb.pdf.

Meyer CG, Papastamatiou YP, Holland KN. 2007. Seasonal, diel, and tidal movements of green jobfish (Aprion virescens, Lutjanidae) at remote Hawaiian atolls: implications for marine protected area design. Marine Biology. 151(6):2133–2143. doi:10.1007/s00227-007-0647-7.

Miles M, Huberman A. 1994. Qualitative data analysis: An expanded sourcebook. 2nd ed. Thousand Oaks, CA: Sage Publications.

Nadon MO. 2017. Stock assessment of the coral reef fishes of Hawaii, 2016. United States NMFS, Pacific Islands Fisheries Science Center (U.S.), United States NO and AA, Coral Reef Conservation Program (U.S.), editors. doi:10.7289/V5/TM-PIFSC-60. https://repository.library.noaa.gov/view/noaa/13291.

Nadon MO, Sculley M, Carvalho F. 2020. Stock assessment of uku (Aprion virescens) in Hawaii, 2020. United States. National Marine Fisheries Service, Pacific Islands Fisheries Science Center (U.S.), editors. doi:10.25923/57nb-8138. https://repository.library.noaa.gov/view/noaa/24190.

Office of Science and Technology. 2018. Implementing a Next Generation Stock Assessment Enterprise: An Update to the NOAA Fisheries Stock Assessment Improvement Plan. U.S. Department of Commerce Report No.: NMFS-F/SPO-183. https://spo.nmfs.noaa.gov/sites/default/files/TMSPO183.pdf.

Richards BL. 2020. Annual Report: Fall 2018 Bottomfish Fishery-Independent Survey in Hawaii (BFISH). United States. National Marine Fisheries Service, Pacific Islands Fisheries Science Center (U.S.), editors. doi:10.25923/nmyh-7c59. https://repository.library.noaa.gov/view/noaa/22925.

Severance C, Franco R, Hamnett M, Anderson C, Aitaoto F. 2017. Effort Triggers, Fish Flow, and Customary Exchange in American Samoa and the Northern Marianas: Critical Human Dimensions of Western Pacific Fisheries. Pacific Science. 67(3):383–393.

Shotwell SK, Dorn M, Deary A, Fissel B, Rogers L, Zador S. 2019. Appendix 1xx. Ecosystem and Socioeconomic Profile of the Walleye Pollock stock in the Gulf of Alaska. In: Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands Regions 2019 Final Crab SAFE. Anchorage, Alaska: North Pacific Fishery Management Council. p. 38. [accessed 2021 Jul 30]. https://meetings.npfmc.org/CommentReview/DownloadFile?p=caaa62af-89e7-4ba7-97a2-f3c06066bc57.pdf&fileName=GOA_Pollock_ESP_Sept_2019.pdf.

Shotwell SK, Fissel B, Hanselman D. 2018. Ecosystem and socioeconomic profile of the Sablefish stock in Alaska. Appendix 3C. In: Assessment of the Sablefish stock in Alaska. Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea Aleutian Islands and Gulf of Alaska. Anchorage, Alaska: North Pacific Fishery Management Council. p. 712–738. [accessed 2021 Jul 30]. https://meetings.npfmc.org/CommentReview/DownloadFile?p=8f5233fb-3b62-4571-9b49-8bb7ce675916.pdf&fileName=ESP_Shotwell.pdf.

Tashakkori A, Teddlie C. 2003. Handbook of Mixed Methods in Social & Behavioral Research. Thousand Oaks, CA: SAGE.

Toonen RJ, Andrews KR, Baums IB, Bird CE, Concepcion GT, Daly-Engel TS, Eble JA, Faucci A, Gaither MR, Iacchei M, et al. 2011. Defining Boundaries for Ecosystem-Based Management: A Multispecies Case Study of Marine Connectivity across the Hawaiian Archipelago. Halpern BS, editor. Journal of Marine Biology. 2011:460173. doi:10.1155/2011/460173.

TuckerWilliams E, Lepczyk CA, Hawkins CT. 2018. Perspectives on developing a non-commercial saltwater fishing license program in Hawai‘i. Marine Policy. 94:174–179. doi:10.1016/j.marpol.2018.05.016.

WPFMC. 2019. Annual Stock Assessment and Fishery Evaluation Report for the Hawaii Archipelago Fishery Ecosystem 2019. Honolulu, Hawai’i: Western Pacific Regional Fisheries Management Council. [accessed 2021 Jul 22]. https://www.wpcouncil.org/wp-content/uploads/2020/07/Hawaii-FEP-SAFE-Report-2019-Final-v5.pdf.

WPFMC. 2020a. Preliminary draft specifying the annual catch limits for the main Hawaiian Island uku fishery for fishing year 2022-2025. Honolulu, Hawai'i. [accessed 2021 Jul 18]. http://www.wpcouncil.org/wp-content/uploads/2020/04/10.D.21-2020-08-13-DRAFT-MHI-Uku-2022-2025-ACL-Specification-Document-v2.0.pdf.

WPFMC. 2020b. Main Hawaiian Island SEEM Working Group meeting. Honolulu, Hawai'i. [accessed 2021 Jul 29]. http://www.wpcouncil.org/wp-content/uploads/2020/04/06.A.12-MHI-Uku-SEEM-WG-Meeting_draft-report.pdf.

Wren JLK, Kobayashi DR, Jia Y, Toonen RJ. 2016. Modeled population connectivity across the Hawaiian Archipelago. PLOS ONE. 11(12):e0167626. doi:10.1371/journal.pone.0167626.

Yletyinen J, Hentati-Sundberg J, Blenckner T, Bodin Orjan. 2018. Fishing strategy diversification and fishers' ecological dependency. Ecology and Society. 23(3). doi:10.5751/ES-10211-230328. https://www.ecologyandsociety.org/vol23/iss3/art28/.

Appendix A: Fisher Panel Interview Guide

Incorporating socioeconomics into stock assessments: A Pilot Project

uku fisher panel interview guide

We invite you to participate in a social science research project with The Joint Institute of Marine and Atmospheric Research (JIMAR)/University of Hawai‘i at Mānoa and NOAA’s Pacific Islands Fisheries Science Center. The purpose of this research is to better understand ecosystem and socioeconomic dynamics of the uku (*Aprion virescens*) fishery in the main Hawaiian Islands. Your participation in this study is voluntary and your responses will not be tied to you or your business in any way. Findings from this study will be presented anonymously or in the aggregate and may be used to improve the stock assessment process, and improve communication about them by fishery managers (The Western Pacific Regional Fishery Management Council and NMFS). Interviews should take 30–40 minutes. If you have any questions please contact Adam Ayers (adam.ayers@noaa.gov, 808-725-5498).

Effort/Sociocultural/Socioeconomic aspects

1. How long have you been fishing / what types of fishing do you do?
2. How long have you been fishing for uku? Why do you target uku?
3. What makes uku special or important to you?
4. How do you like to eat uku / what is your favorite uku recipe?
5. How has uku fishing changed over time?

Probes: habitat, fishing locations.

6. What, if any, fishing gear is unique to uku fishing?

Commercial/Non-Commercial Catch

7. Please describe your typical uku trip. How does that differ from other fishing trips?
   Probes: Location, catch, hours fishing
8. How many of these trips did you take in the past year?

Ecosystem and Socioeconomics

9. What environmental factors are associated with good or bad uku fishing?

Probes: wind, currents, seasonality, day/night, presence of other fish.

10. How often do you see large aggregations of uku?
11. What, if anything makes you shift from fishing for one species to targeting uku on a trip?

Probes: What makes you decide to target uku?

12. What have you observed about uku and its relationship with other species, for example, yellowfin tuna, mahimahi, opelu, white ulua, other species?
13. What interactions with other fish occur when you target uku?

Probes: What do you notice about shark interactions?

Market Demand, Trends

14. Where does most uku catch go?
Probes: fish markets, restaurants, to family/friends, other?

15. How has the market for uku changed since you started fishing?
16. How have non-market uku transactions changed over time?
Probes: Sharing, giving away to friends/family, social media sales, et al?

Management Impacts

17. What is the likelihood that uku are overfished?
Probes: Abundance observations.

18. What would you do if the uku catch limit was reached or some other management measure prevented you fishing for uku?
Probes: Troll, bottomfish, target other species, pursue shore-based employment?

Reporting

19. In your opinion, how accurate are the catch reporting (commercial and non-commercial) and assessment processes?
How could these processes be improved?

20. Anything Else?
21. How has COVID-19 changed your fishing activity?
22. What is something that managers and/or scientists may not know about uku fishing?
23. Do you have anything else you would like to add or any questions?

Thank you for your time and thoughtful responses. If you share your email address, we will send you the study results when we are finished. If not, we will also distribute our findings when the study is completed.