Annual Report: 2020 Fall Bottomfish Fishery-Independent Survey in Hawai‘i

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Executive Summary

The Bottomfish Fishery-Independent Survey in Hawai‘i (BFISH) provides robust estimates of size-structured population abundance and biomass for the main Hawaiian Islands Deep-7 bottomfish complex. These survey data complement and enhance the stock assessment process conducted by the Pacific Islands Fisheries Science Center (PIFSC).

The 2020 BFISH survey comprised 500 primary sampling units (PSUs) across the 8 main Hawaiian Islands. Two sampling gears, cooperative research hook-and-line fishing and stereo camera systems, were deployed at depths ranging from 75 to 400 m from August 15 to November 15, 2020.

In the 2020 BFISH survey, ehu was the most abundant species of the Deep-7 complex, followed by ‘ōpakapaka and kalekale. ‘Ōpakapaka had the highest estimated exploited stock biomass, followed by ehu and kalekale. ‘Ōpakapaka, ehu, and onaga were the three main design species. The estimated stock biomass of ‘ōpakapaka and ehu was approximately 2.335 and 1.945 million lb, respectively. Onaga stock biomass was about 0.739 million lb. Coefficients of variation (CV%) for exploited stock biomass for ehu and ‘ōpakapaka were 17.91 to 32.25, respectively.

To improve overall precision of BFISH surveys, future research will focus on the following:

(1) Increase the number of primary sampling units (PSUs) to optimize future sampling efforts with respect to the number of PSUs required to achieve the desired coefficient of variation (CV) for biomass estimates.

(2) Target sample allocations to better reflect species’ depth preferences.

(3) Invest in technological innovations that better define the unit area sampled and which can increase the depth range of the MOUSS camera system.

(4) Develop methods to improve empirical estimates of the effective sampling area of the MOUSS camera system.

Introduction

Commercial and recreational fishing are important to the economy and culture of Hawai‘i (Haight et al. 1993). The Hawaiian deep-slope (100−400 m) fishery consists of 7 high-value bottomfish species (i.e., 6 snappers and one grouper), hereafter referred to as the Deep 7 (Figure 1) (Western Pacific Regional Fishery Management Council 2010), that account for more than 50% of the total insular commercial catch (Western Pacific Regional Fishery Management Council 2010).

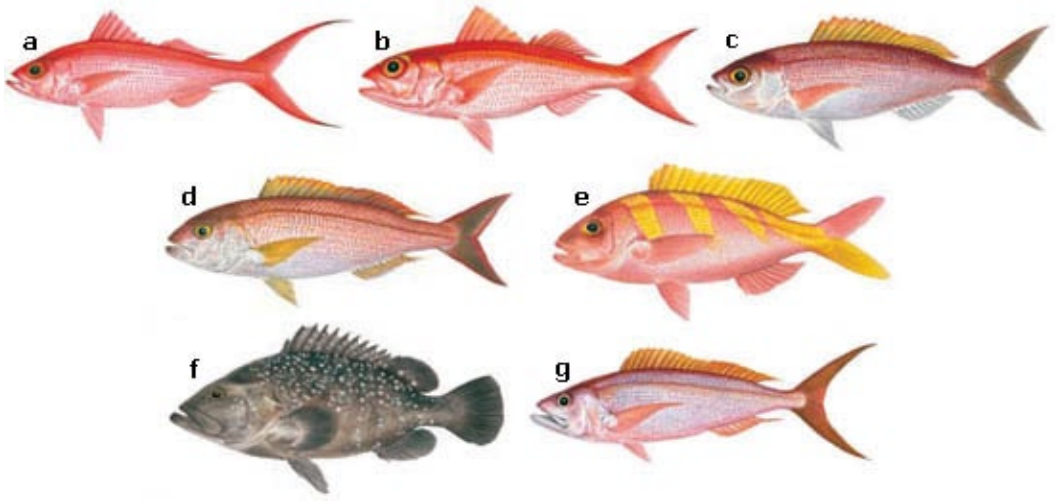

Figure 1. The main Hawaiian Islands "Deep-7" bottomfish complex: (a) Onaga (*Etelis coruscans*), (b) Ehu (*Etelis carbunculus*), (c) Kalekale (*Pristipomoides sieboldii*), (d) ‘Ōpakapaka (*Pristipomoides filamentosus*), (e) Gindai (*Pristipomoides zonatus*), (f) Hapu‘upu‘u (*Hyporthodus quernus*), and (g) Lehi (*Aphareus rutilans*). Artwork by Les Hata (Hawai‘i DAR/DLNR).

Under the Magnuson-Stevens Fishery Conservation and Management Act (United States Congress, 2007), the National Oceanic and Atmospheric Administration (NOAA) Pacific Islands Fisheries Science Center (PIFSC) is responsible for conducting stock assessments of the Deep-7 complex. These assessments determine stock status from which the Western Pacific Regional Fishery Management Council (WPRFMC) recommends annual fishery catch limits.

The conventional stock assessment process requires reliable time-series of catches, fishing effort, and life history demographics to estimate stock abundance trends and evaluate sustainability benchmarks (Quinn and Deriso 1999; Haddon 2011). Until recently, stock assessments for the main Hawaiian Islands Deep-7 bottomfish complex (Brodziak et al. 2014) relied on trends in fishery-dependent catch per unit effort (CPUE). However, fishery-dependent CPUE abundance index can be biased due to nonrandom spatiotemporal distribution of fishing effort and gears, imposed length and catch regulations, market forces, and fisher behavior (Hilborn and Walters 1992; Maunder and Punt 2004; Ault et al. 2014).

PIFSC has continually strived to improve data used in the Deep-7 stock assessments. In 2016 PIFSC implemented a multi-gear Bottomfish Fishery-Independent Survey in Hawai'i (BFISH)

(Richards et al. 2016). There are several key advantages of fishery-independent surveys: (1) they employ formal experimental designs; (2) they control the distribution of fishing effort and gears; (3) they are less influenced by market forces; and, (4) they obtain similar stock size-structured abundance data as fishery-dependent catch sampling programs, but they do so with greater statistical rigor (Ault et al. 1999; Smith et al. 2011). Fishery-independent surveys can be designed to estimate absolute population abundance, thus providing an important independent estimate of stock abundance for use in stock assessment.

The BFISH survey, long a priority for PIFSC (Mace et al. 2001; Ralston et al. 2004), was developed and implemented from 2011 through 2015 using a series of pilot gear calibration studies in the Maui-Nui island region (Richards et al. 2016). The BFISH survey became operational in 2016. Data from the initial full BFISH 2016 survey, included estimates of absolute size-structured abundance and biomass (Ault et al. 2018) that were incorporated into the 2018 benchmark Deep-7 bottomfish stock assessment for the main Hawaiian islands (Langseth et al. 2018). In this report we present results from the fall BFISH 2020 survey.

Methods

The BFISH survey employs a stratified-random sampling design conducted throughout the 8 main Hawaiian islands using 2 gear types: (1) hook-and-line research fishing parallel to what is used in the commercial fishery; and (2) remote drop MOUSS stereo-video cameras (Richards et al. 2016; Amin et al. 2017). The BFISH domain encompasses all main 8 Hawaiian Island mapped bottomfish habitats from 75 to 400 m from the Big Island of Hawai‘i to the island of Ni‘ihau, extending about 600 km and comprising 23,613 500 × 500 m primary sampling units (PSUs) (Figure 2).

A standard research fishing sample consisted of 30 min of active hook-line fishing within a PSU by 1 vessel using 2 lines, each with 4 hooks and 2 bait types (i.e., squid and fish) (Richards et al. 2016). Every fish captured was identified to species, and fork length (FL) was measured to the nearest cm. All Deep-7 individuals were retained and transferred to the PIFSC Fisheries Research and Monitoring Division (FRMD) Life History Program (LHP) for age, growth, sexual maturity, and genetic studies.

For stationary cameras, within each PSU, 2 randomized replicate 15-min deployments were conducted (Richards et al. 2016). In-situ footage was analyzed to generate species-level counts by the MaxN method (Cappo et al. 2006), and measured (FL) to the nearest mm. Replicate counts were averaged for a given sample unit.

The fall BFISH 2020 was conducted from August 15 through November 15, 2020 (Figure 3). Research fishing by the Pacific Islands Fisheries Group (PIFG) sampled 453 PSUs throughout the survey domain from August 15 to November 15, 2019 (Appendix A). Camera operations at 47 PSUs were conducted by PIFG on October 8–13, 2020, around the island of Oahu and Penguin Banks (Figure 3). The restricted camera sampling was due to the COVID-19 pandemic, which required that cameras were deployed from a cooperative research fishing vessel rather than the NOAA Ship *Oscar Elton Sette*. Without a NOAA camera technician aboard, the vessel offloaded cameras to Oahu-based technicians at the end of each day for data download and refitting.

The fall BFISH 2020 employed an updated stratification scheme that involved 24 strata dependent on three principal environmental characteristics: (1) depths; (2) seafloor hardness; and, (3) benthic habitat complexity. The details of the strata and substrata delineation are provided in Table 1 and Table 2. Depths and seafloor hardness were obtained from 5-m resolution multi-beam bathymetry (Hawaii Mapping Research Group 2016) and associated backscatter (Richards et al. 2019). Habitat complexity was defined using arc chord ratio (ACR) values derived from the multi-beam bathymetry.

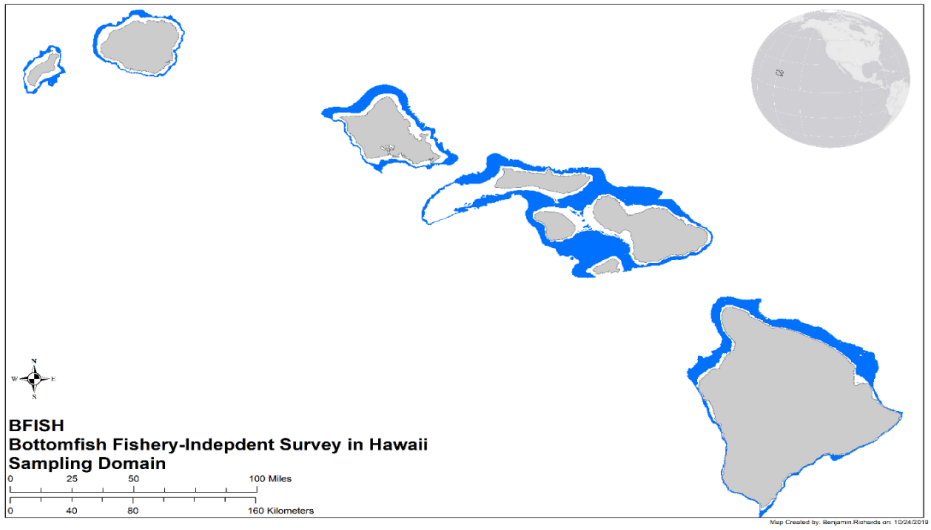

Figure 2. The spatial domain of the Deep-7 bottomfish survey (blue-shaded region) extending from Niʻihau in the northwest to the island of Hawaiʻi in the southeast.

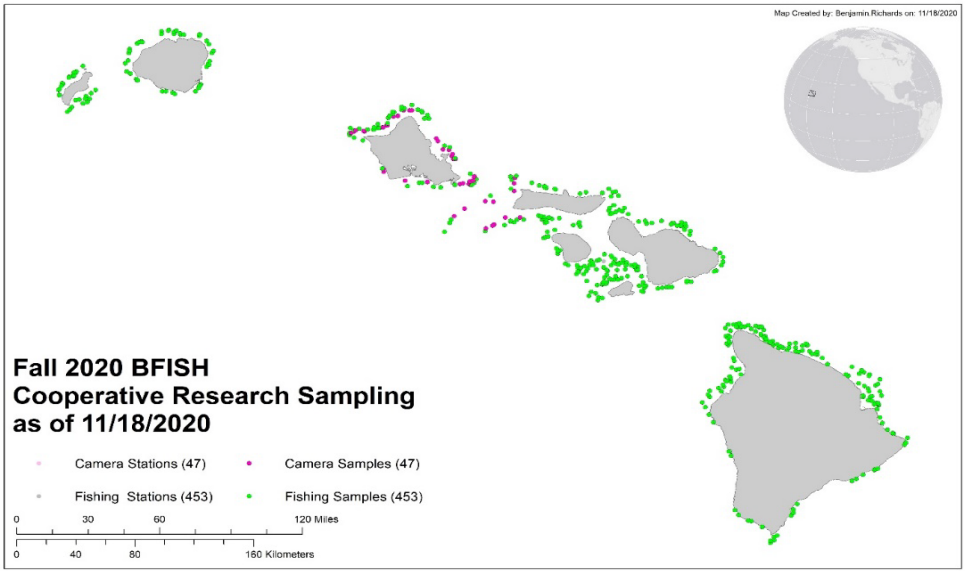

Figure 3. Map of BFISH 2020 sampling locations by gear type. Research fishing operations (green circles) that extended from the big island of Hawaiʻi in the southeast to Niʻihau in the northwest. Camera operations (pink circles) were restricted to the island of Oahu and Penguin Banks.

Table 1. Island-based allocation of PSUs based on the BFISH 2020 24-strata sampling design.

Stratum	Substrata			Island PSU Allocation					
	Depth	Complexity	Hardness	Niʻihau	Kaua i	Oahu	Maui Nui	Big Island	Grand Total
S01	D1	MA1 or MA2	HB1 or HB2 or HB3	2	2	2	2	2	10
S02	D1	MA3	HB1	2	2	2	2	2	10
S03	D1	MA3	HB2		2	2	2	2	8
S04	D1	MA3	HB3			2	2	2	6
S05	D2	MA1	HB1 or HB2	2	2	2	14	4	24
S06	D2	MA1	HB3		2	2	2	2	8
S07	D2	MA2	HB1	2	2	2	8	3	17
S08	D2	MA2	HB2			2	3	3	8
S09	D2	MA2	HB3		2	2	2	2	8
S10	D2	MA3	HB1	2	4	7	39	31	83
S11	D2	MA3	HB2		2	3	8	6	19
S12	D2	MA3	HB3	2	2	2	2	2	10
S13	D3	MA1 or MA2	HB1 or HB2 or HB3		2	2	2	2	8
S14	D3	MA3	HB1	2	2	2	7	3	16
S15	D3	MA3	HB2			2	3	2	7
S16	D3	MA3	HB3	2	2	2	3	5	14
S17	D4	MA1 or MA2	HB1 or HB2	2	2	2	2	2	10
S18	D4	MA1	HB3				2	2	4
S19	D4	MA2	HB3			2	6	2	10
S20	D4	MA3	HB1	2	3	7	26	19	57
S21	D4	MA3	HB2	2	2	4	8	5	21
S22	D4	MA3	HB3	4	5	22	35	24	90
S23	D5	MA1 or MA2	HB1 or HB2 or HB3		2	2	2	2	8
S24	D5	MA3	HB1 or HB2 or HB3	2	2	8	13	19	44
		Grand Total		**28**	**44**	**85**	**195**	**148**	**500**

Table 2. Habitat-based substrata used for the fall BFISH 2020 sampling design.

Depth Substrata	Median Depth (m)	Complexity Substrata	Median ACR	Hardness Substrata	% of PSU px Above Multibeam Backscatter Value 136
D1	≥ 75 & < 110	MA1	< 4	HB1	< 0.24
D2	≥ 110 & < 170	MA2	≥ 4 & < 9	HB2	≥ 0.24 & < 0.46
D3	≥ 170 & <220	MA3	≥ 9	HB3	≥ 0.46
D4	≥ 200 & < 330				
D5	≥ 330 & < 400				

Sampling was optimally allocated amongst the twenty-four (24) survey strata following a Neyman scheme (Cochran 1977). Allocation was carried out in two steps. First, an optimal allocation was determined for each of the three design species (ehu, ʻōpakapaka, onaga). These species-specific allocations were then overlapped to create an optimal composite allocation for the overall survey, including strata common to all species while also incorporating strata important to any one of the three design species. PSUs within strata were randomly selected without replacement from a discrete uniform probability distribution to ensure an equal probability of selection (Law and Kelton 2000). The *effective survey sample size* is the number of PSUs sampled within the preferred depth range for a given species. Domain mapping and survey sample site selection were conducted using ArcGIS (ESRI Inc. 2017) and R (R Development Core Team 2020).

Gears were allocated to PSUs based on a combination of gear-specific depth, logistical constraints as well as regulatory restrictions (e.g., camera samples were preferentially allocated

to areas where fishing is usually restricted). The MOUSS camera system has a depth limit of 250 m (Amin et al. 2017).

A two-stage generalized linear model regression was used to calibrate the relative fishing power of hook-line to camera gears based on comparative gear experiments (Robson 1961; Richards et al. 2016).

Population abundance and biomass estimation for Deep-7 species followed standard protocols for stratified random statistical sampling designs (Cochran 1977; Ault et al. 1999; Lohr 2010; Smith et al. 2011; Ault et al. 2018). The number of fish either caught (fishing) or seen (cameras) per unit sample area searched (i.e., density) was the principal metric used to develop the sampling design.

Estimation of population biomass B entailed expanding the mean biomass per unit $\overline{U}_B$ to the full survey frame following equation (1) (Ault et al. 2018), where, A_i is the area of a grid cell sample unit, a_i is the effective sampling area of the camera gear, and G is the number of grid cells in the survey domain. Mean biomass per sample unit was obtained by converting length to weight of each individual fish via an allometric weight-length function, and then summing the weights for all observed fish by species. Allometric functions were developed for each Deep-7 species using paired weight-length observations collected in the Hawaiian Islands by PIFSC scientists. All computations were carried out using the R software package (R Development Core Team 2020).

$$B = \overline{U}_B \frac{A_i}{a_i} G \quad \textbf{(1)}$$

Results

The fall BFISH 2020 comprised 500 primary sampling units (PSUs) selected under the stratified-random experimental design. A total of 558 Deep-7 individuals, including 322 ehu, 71 ʻōpakapaka, and 59 onaga were captured, along with 307 bycatch individuals (Table 3).

Table 3. Numbers (n) of individual fish (Deep 7 and other species) caught during fall BFISH 2020 research fishing operations. Full list gives all species caught over all survey years.

Species Code	Common Name	Scientific Name	n
Deep 7			**558**
ETCA	Ehu	*Etelis carbunculus*	322
PRFI	ʻŌpakapaka	*Pristipomoides filamentosus*	71
ETCO	Onaga	*Etelis coruscans*	59
PRZO	Gindai	*Pristipomoides zonatus*	54
PRSI	Kalekale	*Pristipomoides sieboldii*	32
HYQU	Hapuʻupuʻu	*Hyporthodus quernus*	9
APRU	Lehi	*Aphareus rutilans*	1
non-Deep 7			**307**
SQMI	Green eye shark	*Squalus hawaiiensis*	174
SEDU	Kahala	*Seriola dumerili*	50
POBE	Deep-sea Moi	*Polymixia berndti*	13
APVI	Uku	*Aprion virescens*	11
POMA	Hogo	*Pontinus macrocephalus*	8
BOAL	Table Boss	*Bodianus albotaeniatus*	5
LUKA	Taʻape	*Lutjanus kasmira*	4

Species Code	Common Name	Scientific Name	n
TRIG	Triggerfish sp.	*Balistid sp.*	3
CAUN	Hawaiian Sunrise Perch	*Caprodon unicolor*	3
PUFF	Puffer sp.	*Tetraodontid sp.*	3
APFU	Waha Nui	*Aphareus furca*	3
GYSP	Moray eel	*Gymnothorax sp.*	2
SHAR	Reef Shark	*Carcharhinus sp.*	2
ERSC	Golden Kale	*Erythrocles scintillans*	2
SHAR	Shark (misc.)	*Carcharhinus sp.*	2
FLOU	Flounder	*Pleuronectiformes sp.*	2
EUIL	Monchong	*Eumegistus illustris*	2
COJA	Aweoweo	*Cookeolus japonicus*	2
CHCH	Green-spotted duckbill	*Chrionema chryseres*	1
TRMY	Lizard fish	*Trachinocephalus myops*	1
SPHE	Kawelea	*Sphyraena helleri*	1
CAME	ʻOmilu	*Caranx melampygus*	1
CAIG	Ulua	*Caranx ignobilis*	1
ACDU	Palani	*Acanthurus dussumieri*	1
ELBI	Kamanu	*Elagatis bipinnulata*	1
CASP	Papio	*Caranx sp.*	1
OCSP	Tako	*Octopus sp.*	1
PSDE	Butaguchi	*Pseudocaranx cheilio*	1
MUPF	Weke Ula	*Mulloidichthys pfluegeri*	1
ERSC	Golden Kale	*Erythrocles scintillans*	1
POBE	Deep-sea Moi	*Polymixia berndti*	1
CAML	Shark (Black tip)	*Carcharhinus melanopterus*	1
PORC	Balloonfish	*Tetraodontinae sp.*	1
PAMU	Moana	*Parupeneus multifasciatus*	1
	Grand Total		**865**

A total of 311 Deep-7 individuals were observed by the MOUSS camera system. Kalekale was the most abundant (n = 240), followed by onaga (n = 49) and ʻōpakapaka and ehu (n = 11 for both). Accurate length measurements were obtainable for all 558 Deep-7 individuals captured during research fishing operations and for 140 of the 311 fishes observed by the MOUSS camera system (Table 4).

Table 4. Numbers (n) and sizes (cm FL) of Deep-7 species caught during research fishing operations or observed (MaxN) by MOUSS camera during the fall BFISH 2020 survey.

	RESEARCH FISHING					MOUSS CAMERA					
		Fork Length (cm)						Fork Length (cm)			
Species	**n**	**Min**	**Mean**	**Max**	**SD**	**MaxN**	**measured**	**Min**	**Mean**	**Max**	**SD**
Ehu	322	12.0	32.1	60.0	8.6	11	11	34.8	41.1	52.1	5.2
Gindai	54	18.5	33.9	43.0	5.0	6	6	15.3	22.9	34.4	8.6
Hapuʻupuʻu	9	52.0	66.4	78.0	8.6	1	1	69.9	69.9	69.9	-
Kalekale	42	19.2	34.1	46.0	5.3	240	71	6.2	16.4	36.7	11.7
Lehi	1	51.0	51.0	51.0	-	4	4	62.1	65.4	71.9	4.4
Onaga	59	17.5	39.5	87.0	14.5	49	47	16.7	46.9	73.1	12.2
ʻŌpakapaka	71	18.0	37.2	63.0	11.5	11	11	34.8	41.1	52.1	5.2
TOTAL Deep 7	**558**					**311**	**140**				

Kalekale had the largest absolute abundance estimate, followed by ehu and ʻōpakapaka (Table 5). ʻŌpakapaka had the greatest exploited stock biomass, followed by ehu and kalekale. The estimated population biomass of ʻōpakapaka and onaga was approximately 1.059 and 0.335 million kg, respectively. Ehu stock biomass was about 0.882 million kg. Coefficients of variation (CV%) for exploited stock biomass were 17.9 and 32.2 for ehu and ʻōpakapaka, the two main design species.

Table 5. Fall BFISH 2020 survey statistics: catch per unit effort (CPUE), and estimated exploited species stock abundance and biomass (fishing and camera gears combined).

Species	CPUE	SE	Abundance	SE	Biomass (kg)	SE	CV (%)
Ehu	0.3797	0.0680	936,341	167,740.1	882,078.0	151,840.1	17.9
Gindai	0.0694	0.0167	171,151	41,151.8	174,479.1	45,378.2	24.0
Hapuʻupuʻu	0.0141	0.0053	34,655	13,050.7	212,322.2	85,781.1	37.7
Kalekale	0.4152	0.1383	1,024,052	341,018.9	781,899.5	248,643.1	33.3
Lehi	0.0035	0.0025	8,751	6,281.4	23,624.2	16,357.7	71.8
Onaga	0.0762	0.0193	188,001	47,576.4	335,385.6	99,570.5	25.3
ʻŌpakapaka	0.2796	0.0902	689,596	222,374.6	1,059,126.4	291,476.4	32.2
TOTAL					**3,468,915.0**	**435,243.3**	

Trends in exploited stock relative biomass varied among the species with few significant differences among years (Table 6, Figure 4, and Figure 5) and little change in species-specific size distributions (Figure 6). Survey precision ranged from a CV of 17.9% for ehu to 37.7% for hapuʻupuʻu, with CVs of 32.2% and 25.3% for ʻōpakapaka and onaga, respectively (Table 5, Figure 7). The principal conclusion to be drawn are that the year-to-year variance in biomass estimates is decreasing (likely due to refinement of the experimental design), within-year variance is decreasing, and overall survey precision is increasing. Additionally, the composition of the Deep-7 bottomfish community in terms of stock biomass is generally equally balanced between the 3 design species.

Table 6. Exploited phase abundance and biomass indices from the 2016–2020 BFISH surveys.

		No. of		CPUE, number		CPUE, biomass (kg)		Abundance (number)		Biomass (kg)	
Species	Year	Strata	n	Mean	SE	Mean	SE	Total	SE	Total	SE
Ehu	2016	9	319	0.3821	0.0711	0.3728	0.0737	942,393	175,428	919,452	181,683
Ehu	2017	9	449	0.3145	0.0901	0.3496	0.1020	775,717	222,139	862,203	251,494
Ehu	2018	9	437	0.2198	0.0565	0.2508	0.0721	541,935	139,395	618,476	177,760
Ehu	2019	9	470	0.3848	0.0683	0.3938	0.0769	948,935	168,360	971,152	189,688
Ehu	2020	24	499	0.3797	0.0680	0.3577	0.0616	936,341	167,740	882,078	151,840
Gindai	2016	9	326	0.0213	0.0072	0.0209	0.0076	52,590	17,855	51,604	18,835
Gindai	2017	9	448	0.0132	0.0043	0.0137	0.0044	32,508	10,489	33,816	10,847
Gindai	2018	9	441	0.0118	0.0050	0.0128	0.0052	29,186	12,215	31,641	12,907
Gindai	2019	9	475	0.0212	0.0063	0.0227	0.0078	52,354	15,459	55,896	19,149
Gindai	2020	24	499	0.0694	0.0167	0.0707	0.0184	171,151	41,152	174,479	45,378
Hapuʻupuʻu	2016	9	327	0.0067	0.0040	0.0556	0.0330	16,507	9,918	137,132	81,386
Hapuʻupuʻu	2017	9	447	0.0070	0.0028	0.0389	0.0173	17,240	6,938	95,833	42,768
Hapuʻupuʻu	2018	9	441	0.0198	0.0082	0.1018	0.0408	48,949	20,183	251,133	100,586
Hapuʻupuʻu	2019	9	475	0.0047	0.0026	0.0226	0.0119	11,607	6,433	55,660	29,226
Hapuʻupuʻu	2020	24	499	0.0141	0.0053	0.0861	0.0348	34,655	13,051	212,322	85,781
Kalekale	2016	9	319	0.1636	0.0459	0.1500	0.0435	403,394	113,100	369,934	107,307
Kalekale	2017	9	441	0.5378	0.1088	0.4653	0.0948	1,326,264	268,416	1,147,403	233,870
Kalekale	2018	9	440	0.2534	0.0706	0.2301	0.0638	624,930	174,137	567,353	157,460
Kalekale	2019	9	475	0.2306	0.0824	0.2007	0.0742	568,660	203,191	495,057	182,942

Species	Year	No. of Strata	n	CPUE, number		CPUE, biomass (kg)		Abundance (number)		Biomass (kg)	
				Mean	SE	Mean	SE	Total	SE	Total	SE
Kalekale	2020	24	499	0.4152	0.1383	0.3171	0.1008	1,024,052	341,019	781,899	248,643
Lehi	2016	9	325	0.0185	0.0123	0.0690	0.0514	45,733	30,332	170,059	126,670
Lehi	2017	9	444	0.0285	0.0158	0.0746	0.0441	70,270	38,934	184,039	108,741
Lehi	2018	9	438	0.0181	0.0137	0.0561	0.0425	44,580	33,811	138,280	104,872
Lehi	2019	9	475	0.0033	0.0020	0.0130	0.0084	8,110	4,936	32,018	20,629
Lehi	2020	24	499	0.0035	0.0025	0.0096	0.0066	8,751	6,281	23,624	16,358
Onaga	2016	9	326	0.0728	0.0269	0.1830	0.0872	179,630	66,349	451,310	214,947
Onaga	2017	9	444	0.1720	0.0594	0.4290	0.1599	424,187	146,603	1,057,903	394,391
Onaga	2018	9	441	0.0665	0.0244	0.1654	0.0701	164,059	60,274	408,004	172,812
Onaga	2019	9	475	0.0509	0.0230	0.2163	0.1049	125,554	56,670	533,442	258,800
Onaga	2020	24	499	0.0762	0.0193	0.1360	0.0404	188,001	47,576	335,386	99,570
ʻŌpakapaka	2016	9	319	0.6877	0.2293	1.5231	0.5297	1,695,941	565,522	3,756,272	1,306,338
ʻŌpakapaka	2017	9	438	0.4057	0.0901	0.8600	0.1659	1,000,451	222,237	2,120,883	409,208
ʻŌpakapaka	2018	9	436	0.2435	0.0715	0.5633	0.1579	600,414	176,402	1,389,282	389,363
ʻŌpakapaka	2019	9	472	0.2730	0.0627	0.5984	0.1454	673,334	154,681	1,475,671	358,653
ʻŌpakapaka	2020	24	499	0.2796	0.0902	0.4295	0.1182	689,596	222,375	1,059,126	291,476
Deep 7	2016	9								5,855,762	1,349,173
Deep 7	2017	9								5,502,080	674,323
Deep 7	2018	9								3,404,169	509,060
Deep 7	2019	9								3,618,897	516,435
Deep 7	2020	24								3,468,915	435,243

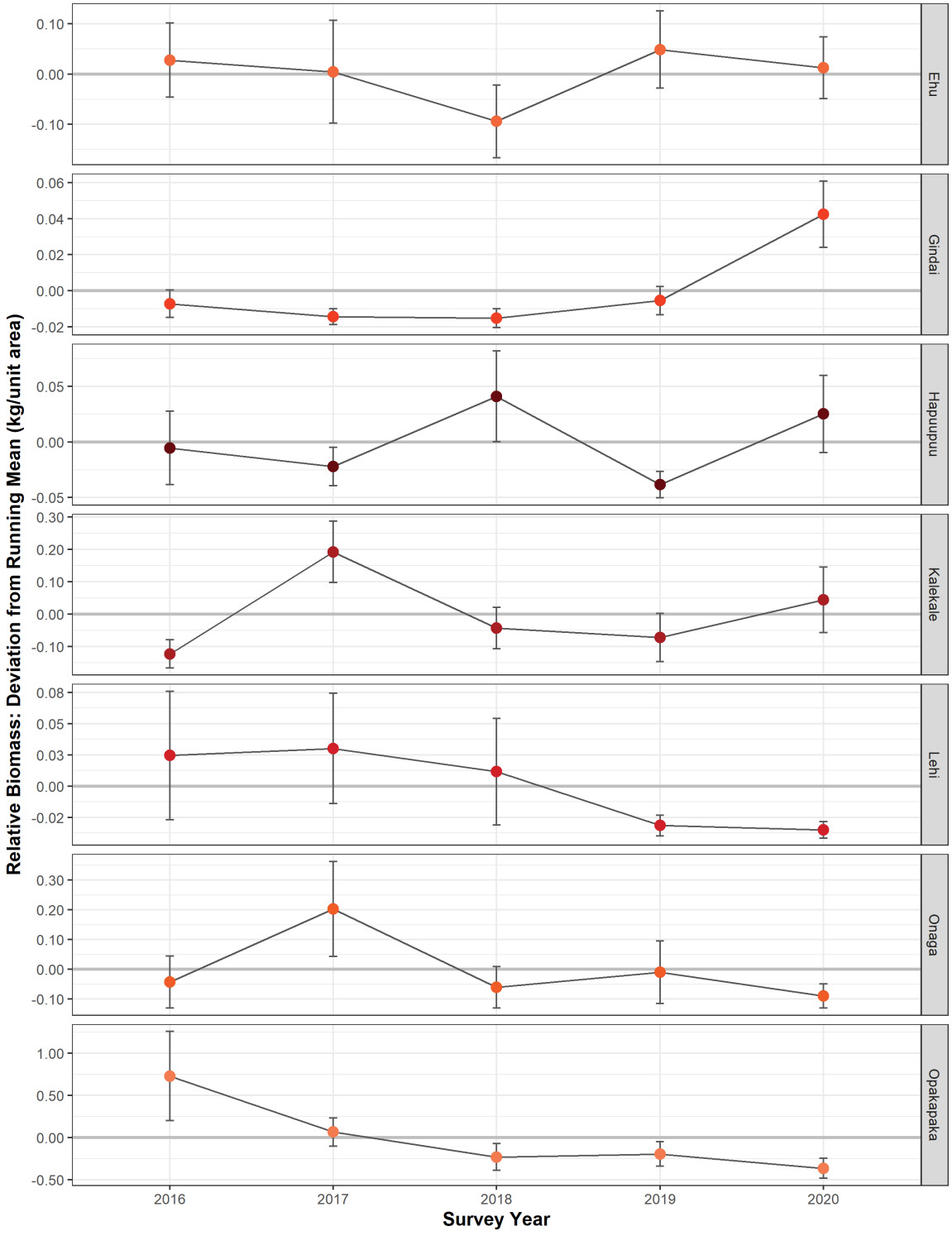

Figure 4. Annual Deep-7 relative biomass (± 1 SE) by species in the exploited phase (> 29 cm), relative to the 5-year running mean (horizontal gray line). High 2016 ‘ōpakapaka biomass was due to unusual catch of several individuals in low slope, soft-bottom habitats, which greatly affected design-based estimates.

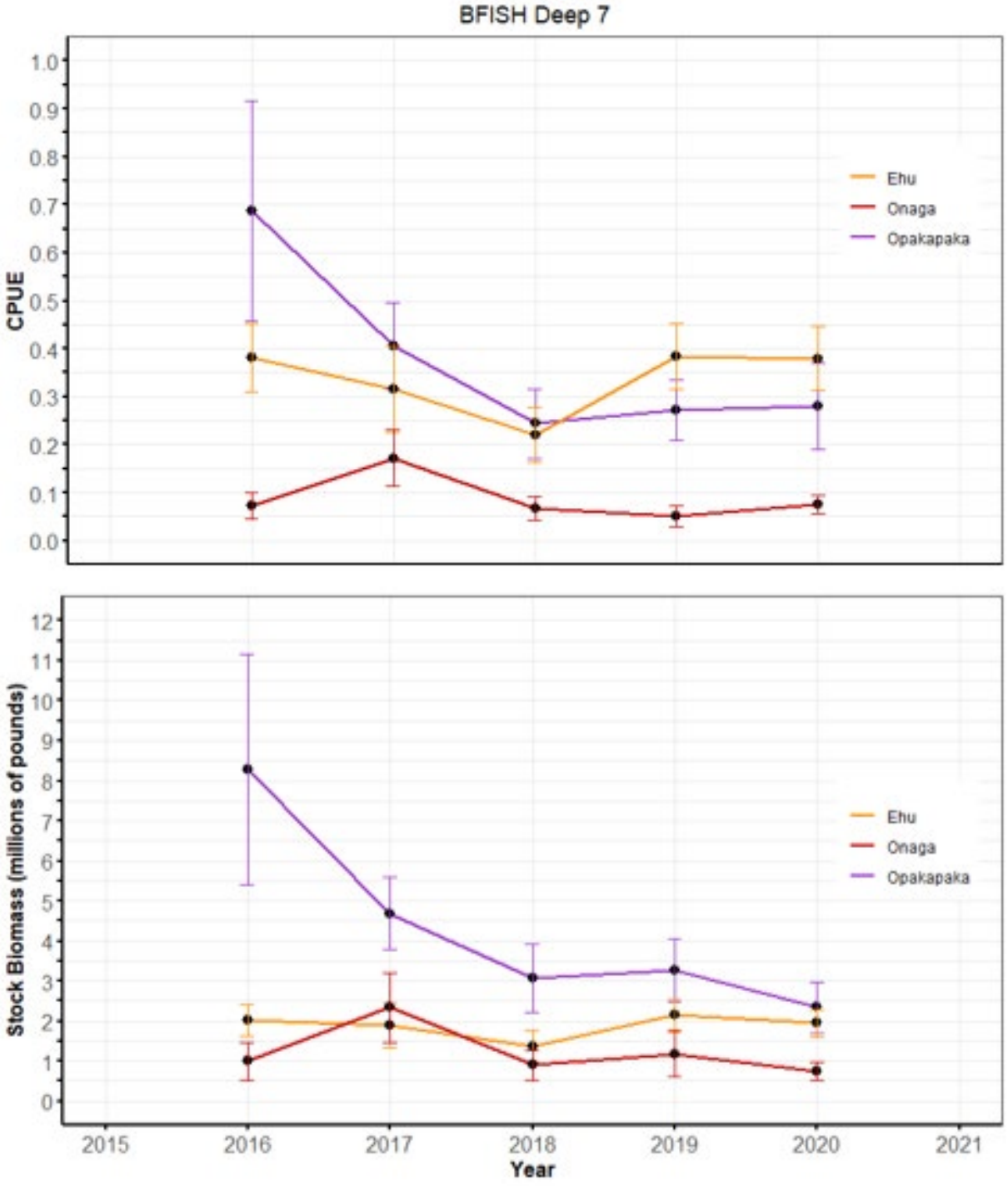

Figure 5. Annual survey estimates for three design species: (A) stock density (CPUE ± 1 SE); and, (B) stock biomass (± 1 SE).

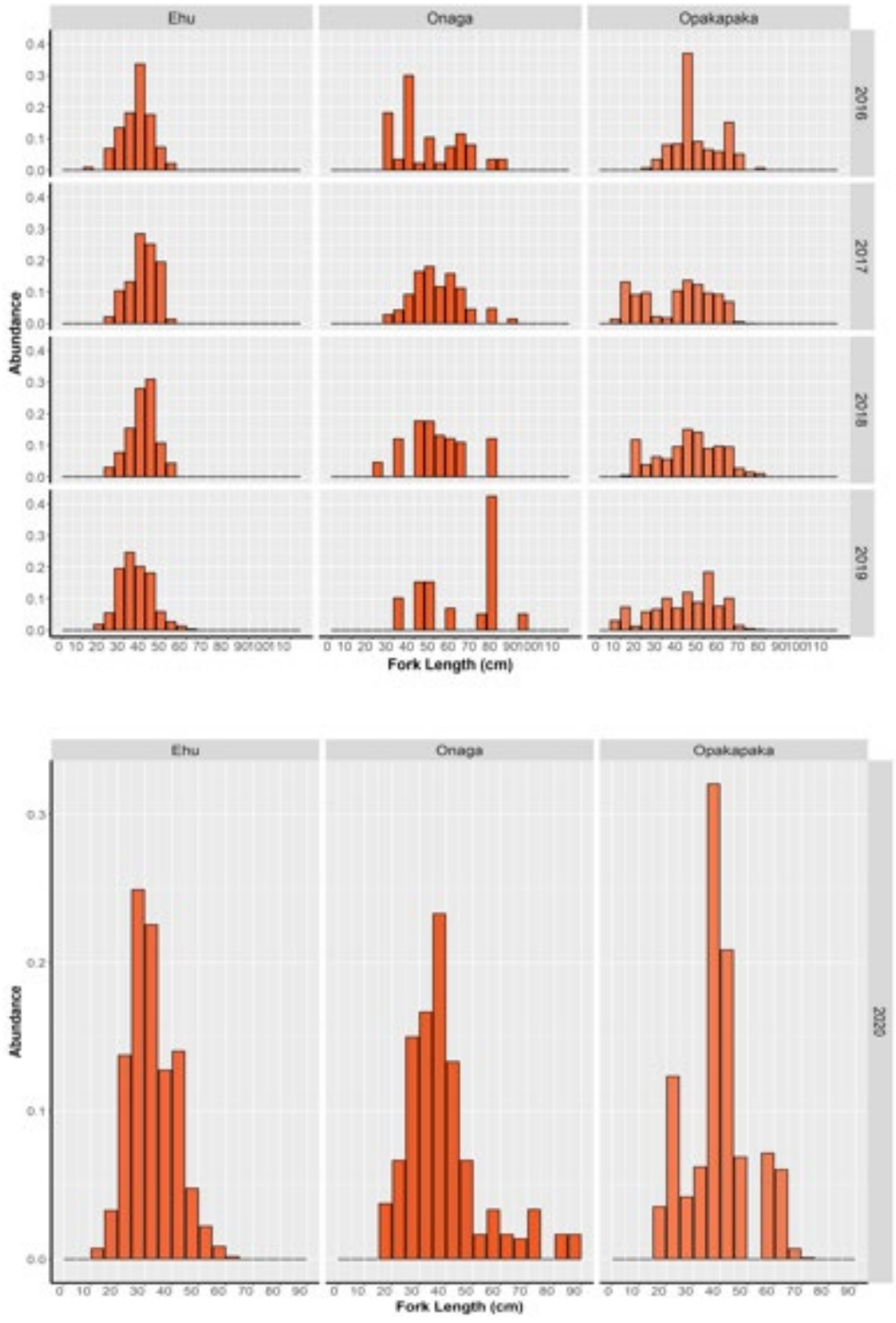

Figure 6. Length frequencies for ʻōpakapaka, onaga, and ehu from the 2016–2019 & 2020 BFISH surveys based on combined research fishing and MOUSS camera data. Exploited phase is >29 cm.

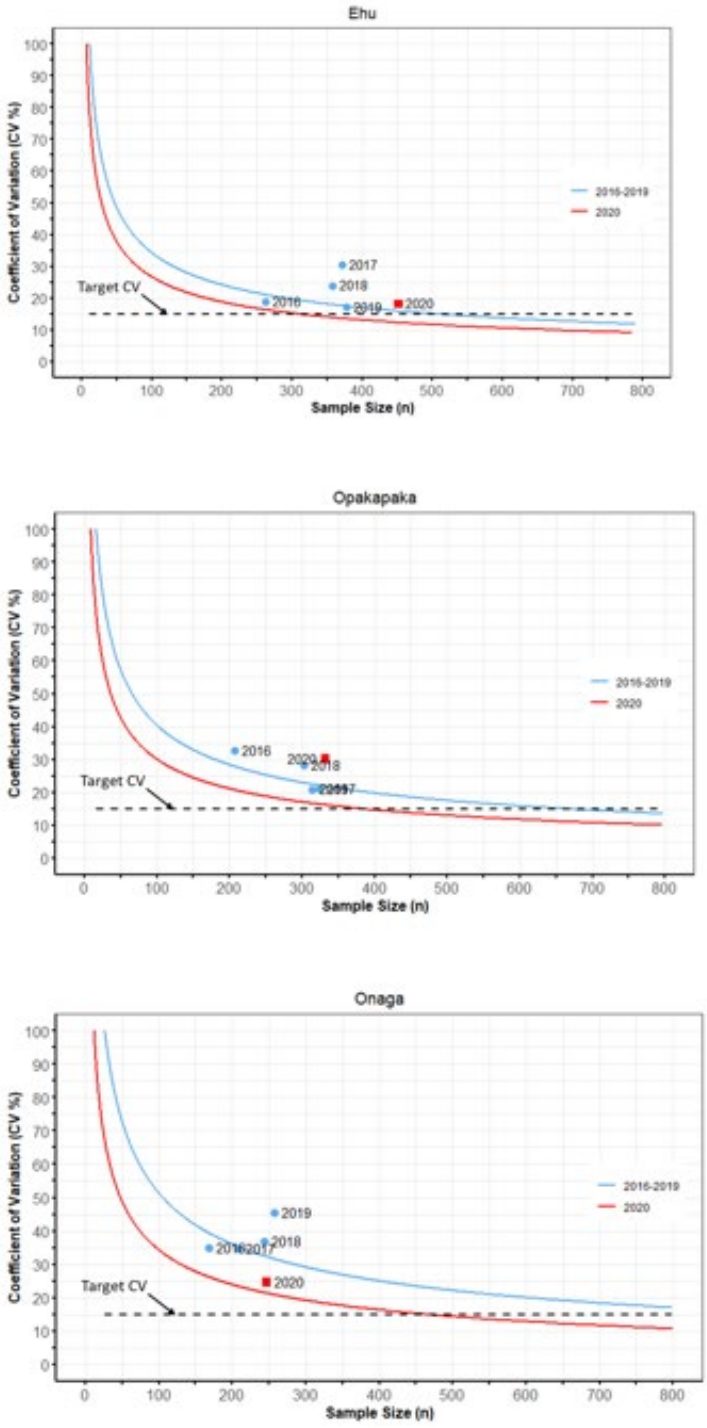

Figure 7. Yearly species-specific survey performance (CV of population density) vs. effective sample size with optimal Neyman curves for the three BFISH design species (ehu, ʻōpakapaka, onaga) and two survey periods (2016–2019 & 2020). The 2020 24-strata design (orange curve) shows marked improvement over the 2016–2019 9-strata design (blue curve). Target CV of 15% is indicated by the dashed horizontal line.

Discussion

The fall 2020 BFISH mission marks the 5-year anniversary of the operational bottomfish survey in Hawai‘i, the first survey in Hawai‘i designed expressly to provide fishery-independent estimates of size-structured abundance and biomass for use in Deep-7 bottomfish stock assessments (Langseth et al., 2018; Ault et al., 2018). Over the years, the cooperative research and public-private partnership between the Pacific Islands Fisheries Science Center, the Pacific Islands Fisheries Group, the University of Miami Rosenstiel School of Marine and Atmospheric Science, Kendall Enterprises, and Lynker Technologies has developed into a longstanding and robust partnership, culminating in a successful 2020 survey, despite the COVID-19 pandemic. The 2020 BFISH was the first survey in which all gears—fishing and cameras—were fielded entirely by cooperative research fishers, without direct field support by PIFSC staff or NOAA Research Vessels.

The 2020 estimated an exploited Deep-7 biomass of 3,468.92 mt (7.65 million lb) suggests that the 2020 annual catch limit of 492,000 lb allocated by the WPRFMC represents approximately 6% of the exploited stock biomass. While there have been some fluctuations in Deep-7 biomass over the 2016–2020 survey years, trends in the principal fishery species (‘ōpakapaka and onaga) have been relatively stable (Figure 4). Recent declines in ‘ōpakapaka and onaga are noteworthy, but may be due to changes in, and imperfect allocation within, the newly developed 24-level stratification. Continued declines in 2021 survey estimates could be cause for concern. Likewise, the marked increase in estimated gindai and hapu‘upu‘u biomass may be due to increased sampling within strata preferred by these species. As mentioned in earlier reports, the markedly higher ‘ōpakapaka biomass in 2016 was inflated by two instances in which ‘ōpakapaka were caught by research fishers in soft-bottom low-relief habitats. Because of the prevalence of this habitat type within the survey domain, these few instances had a substantial effect on our domain-level estimates.

The BFISH survey sampling design is focused on ‘ōpakapaka, ehu, and onaga with a goal of achieving a 15% CV. Since 2016, survey performance has ranged from of 16% to 30% CV for these species. The fall 2020 BFISH achieved a CV of 32.2% for ‘ōpakapaka, 25.3% for onaga, and 17.9% for ehu (Table 5, Figure 7). The evolution from a 9- to 24-level stratification has greatly improved optimal survey precision, evidenced by the leftward and downward movement of the Neyman curve shown in Figure 7. Under the 9-level stratification used from 2016 to 2019, 508, 669, and 999 primary sampling units would be needed to achieve a 15% CV for ehu, ‘ōpakapaka, and onaga, respectively. Under the 24-level stratification developed for 2020, this drops to 310, 385, and 467; a species-specific savings of 197–532 samples per year (Table 7). As the Neyman curves for the 24-level stratification are improved from the 9-factor stratification, the deviation between the Neyman curve and the 2020 precision point for ‘ōpakapaka (Figure 7) is likely due to a misallocation of samples, or to misclassification of PSUs based on imperfect mapping data.

Table 7. Comparison of number of primary sampling units (PSUs) required to achieve 15% CV for each of the design species under the 9- and 24-level stratifications used in the 2016–2019 and 2020 BFISH surveys, respectively.

	PSU needed to achieve 15% CV		
Species	**9 Strata**	**24 Strata**	**Δ**
Ehu	508	310	197
ʻŌpakapaka	669	385	283
Onaga	999	467	532

To improve overall accuracy and precision of BFISH surveys, future research should focus on refining estimates of the effective sampling area of the MOUSS camera system through empirical field experiments. At present, this remains the greatest liability to survey and provides the greatest source of uncertainty for the biomass estimates provided for the stock assessment. Additionally, effort should be made to (1) continue to refine PSU metrics of habitat complexity (e.g., bottom hardness, rugosity, etc.); (2) invest in technological innovations to extend the visual depth range of the MOUSS camera to cover the full depth range of the stock. This could be conducted through artificial lighting systems that do not produce behavioral responses in the test subjects or through improved low-light sensitivity.

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Appendix A: Primary Sampling Units (PSUs) Sampled by Hook-and-Line Fishing Gear During the Fall 2020 BFISH with Location, Stratum, and Vessel

SAMPLE_DATE	Island	PSU	lat_deg	lon_deg	STRATA_2020	VESSEL	GEAR
9/12/2020	Maui Nui	19111	N20° 53.796'	W157° 6.767'	S22	*ALICE*	Fishing
9/12/2020	Maui Nui	17702	N20° 49.677'	W157° 1.919'	S20	*ALICE*	Fishing
9/12/2020	Maui Nui	17416	N20° 48.587'	W157° 1.357'	S20	*ALICE*	Fishing
9/12/2020	Maui Nui	17417	N20° 48.583'	W157° 1.069'	S20	*ALICE*	Fishing
9/12/2020	Maui Nui	17489	N20° 48.848'	W157° 0.489'	S10	*ALICE*	Fishing
9/12/2020	Maui Nui	17073	N20° 47.503'	W157° 1.371'	S20	*ALICE*	Fishing
9/12/2020	Maui Nui	15398	N20° 43.406'	W156° 58.544'	S10	*ALICE*	Fishing
9/12/2020	Maui Nui	15140	N20° 42.850'	W156° 57.400'	S10	*ALICE*	Fishing
9/28/2020	Oahu	37086	N21° 30.177'	W157° 43.078'	#N/A	*ALICE*	Fishing
9/28/2020	Oahu	37147	N21° 30.735'	W157° 45.100'	S20	*ALICE*	Fishing
9/28/2020	Oahu	36468	N21° 25.826'	W157° 41.090'	S20	*ALICE*	Fishing
8/26/2020	Oahu	40202	N21° 45.745'	W158° 0.637'	S22	*EBISUI III*	Fishing
8/26/2020	Oahu	40201	N21° 45.747'	W158° 0.928'	S22	*EBISUI III*	Fishing
8/26/2020	Oahu	40318	N21° 46.290'	W158° 1.214'	S22	*EBISUI III*	Fishing
8/26/2020	Oahu	40077	N21° 45.210'	W158° 1.802'	S16	*EBISUI III*	Fishing
8/26/2020	Oahu	39808	N21° 44.142'	W158° 4.710'	S21	*EBISUI III*	Fishing
8/26/2020	Oahu	39873	N21° 44.417'	W158° 5.288'	S22	*EBISUI III*	Fishing
8/26/2020	Oahu	39679	N21° 43.603'	W158° 5.293'	S22	*EBISUI III*	Fishing
8/26/2020	Oahu	39502	N21° 42.797'	W158° 6.458'	S22	*EBISUI III*	Fishing
8/26/2020	Oahu	39335	N21° 41.987'	W158° 7.043'	S22	*EBISUI III*	Fishing
8/26/2020	Oahu	38941	N21° 39.820'	W158° 7.346'	S14	*EBISUI III*	Fishing
8/27/2020	Oahu	38614	N21° 38.205'	W158° 9.385'	S20	*EBISUI III*	Fishing
8/27/2020	Oahu	38880	N21° 39.568'	W158° 11.117'	S24	*EBISUI III*	Fishing
8/27/2020	Oahu	38530	N21° 37.939'	W158° 10.546'	S22	*EBISUI III*	Fishing
8/27/2020	Oahu	38527	N21° 37.944'	W158° 11.416'	S22	*EBISUI III*	Fishing
8/27/2020	Oahu	38603	N21° 38.220'	W158° 12.574'	S24	*EBISUI III*	Fishing
8/27/2020	Oahu	38359	N21° 37.407'	W158° 12.578'	S22	*EBISUI III*	Fishing
8/27/2020	Oahu	38358	N21° 37.409'	W158° 12.868'	S22	*EBISUI III*	Fishing
9/28/2020	Oahu	38350	N21° 37.419'	W158° 15.187'	S22	*EBISUI III*	Fishing
9/28/2020	Oahu	38420	N21° 37.704'	W158° 18.374'	S15	*EBISUI III*	Fishing
9/28/2020	Oahu	38250	N21° 37.170'	W158° 20.406'	S17	*EBISUI III*	Fishing
9/28/2020	Oahu	38491	N21° 37.989'	W158° 21.852'	S24	*EBISUI III*	Fishing
9/28/2020	Oahu	37923	N21° 36.093'	W158° 22.150'	S22	*EBISUI III*	Fishing
9/28/2020	Oahu	37845	N21° 35.821'	W158° 21.861'	S22	*EBISUI III*	Fishing
9/28/2020	Oahu	37691	N21° 35.280'	W158° 22.153'	S22	*EBISUI III*	Fishing
9/28/2020	Oahu	37498	N21° 34.189'	W158° 20.419'	S15	*EBISUI III*	Fishing
9/28/2020	Oahu	37359	N21° 33.090'	W158° 16.948'	S12	*EBISUI III*	Fishing
9/29/2020	Oahu	39320	N21° 41.630'	W157° 52.836'	S20	*EBISUI III*	Fishing
9/29/2020	Oahu	39326	N21° 41.618'	W157° 51.096'	S24	*EBISUI III*	Fishing
9/29/2020	Oahu	39612	N21° 42.977'	W157° 51.666'	S24	*EBISUI III*	Fishing
9/29/2020	Oahu	39846	N21° 44.075'	W157° 53.687'	S22	*EBISUI III*	Fishing
9/29/2020	Oahu	39978	N21° 44.619'	W157° 53.973'	S20	*EBISUI III*	Fishing
9/29/2020	Oahu	40099	N21° 45.170'	W157° 55.420'	S20	*EBISUI III*	Fishing
9/29/2020	Oahu	40498	N21° 47.082'	W157° 57.727'	S24	*EBISUI III*	Fishing
9/7/2020	Oahu	34929	N21° 17.356'	W157° 32.780'	S19	*AMY C*	Fishing
9/7/2020	Oahu	35428	N21° 18.716'	W157° 33.345'	S22	*AMY C*	Fishing
9/7/2020	Oahu	35622	N21° 19.544'	W157° 35.072'	S20	*AMY C*	Fishing
9/7/2020	Oahu	34176	N21° 16.009'	W157° 33.660'	S19	*AMY C*	Fishing
9/7/2020	Oahu	33695	N21° 15.203'	W157° 34.536'	S23	*AMY C*	Fishing
9/7/2020	Oahu	33693	N21° 15.208'	W157° 35.114'	S17	*AMY C*	Fishing
9/7/2020	Oahu	33672	N21° 15.257'	W157° 41.184'	S21	*AMY C*	Fishing
9/7/2020	Oahu	33671	N21° 15.260'	W157° 41.473'	S21	*AMY C*	Fishing
9/12/2020	Maui Nui	25799	N21° 1.901'	W157° 4.645'	S20	*AMY C*	Fishing
9/12/2020	Maui Nui	25225	N21° 1.346'	W157° 3.498'	S20	*AMY C*	Fishing
9/12/2020	Maui Nui	25523	N21° 1.584'	W157° 0.609'	S11	*AMY C*	Fishing
9/12/2020	Maui Nui	22825	N20° 58.809'	W156° 55.165'	S05	*AMY C*	Fishing
9/12/2020	Maui Nui	23345	N20° 59.326'	W156° 53.138'	S14	*AMY C*	Fishing
9/12/2020	Maui Nui	23869	N20° 59.864'	W156° 52.842'	S14	*AMY C*	Fishing
9/12/2020	Maui Nui	22334	N20° 58.235'	W156° 52.577'	S12	*AMY C*	Fishing
9/12/2020	Maui Nui	21093	N20° 56.998'	W157° 2.401'	S02	*AMY C*	Fishing
9/12/2020	Maui Nui	19350	N20° 54.319'	W157° 5.031'	S07	*AMY C*	Fishing
9/13/2020	Maui Nui	19226	N20° 54.061'	W157° 6.187'	S21	*AMY C*	Fishing

SAMPLE_DATE	Island	PSU	lat_deg	lon_deg	STRATA_2020	VESSEL	GEAR
9/13/2020	Maui Nui	20471	N20° 56.218'	W157° 5.295'	S20	*AMY C*	Fishing
9/13/2020	Maui Nui	23560	N20° 59.750'	W157° 6.116'	S22	*AMY C*	Fishing
9/13/2020	Maui Nui	23825	N21° 0.014'	W157° 5.535'	S22	*AMY C*	Fishing
9/13/2020	Maui Nui	24094	N21° 0.292'	W157° 6.109'	S22	*AMY C*	Fishing
9/13/2020	Maui Nui	24932	N21° 1.101'	W157° 5.810'	S21	*AMY C*	Fishing
9/27/2020	Oahu	33107	N21° 14.215'	W157° 46.686'	S16	*AMY C*	Fishing
9/27/2020	Oahu	33233	N21° 14.506'	W157° 49.574'	S22	*AMY C*	Fishing
9/30/2020	Maui Nui	34809	N21° 16.956'	W157° 18.906'	S19	*AMY C*	Fishing
9/30/2020	Maui Nui	35355	N21° 18.317'	W157° 19.469'	S19	*AMY C*	Fishing
9/30/2020	Maui Nui	35444	N21° 18.564'	W157° 17.152'	S20	*AMY C*	Fishing
9/30/2020	Maui Nui	32810	N21° 13.437'	W157° 19.235'	S20	*AMY C*	Fishing
9/30/2020	Maui Nui	31412	N21° 10.804'	W157° 27.354'	S22	*AMY C*	Fishing
9/3/2020	Kauai	42446	N21° 56.930'	W159° 45.440'	S22	*YUKIE-LYNN*	Fishing
9/3/2020	Kauai	42447	N21° 56.932'	W159° 45.150'	S21	*YUKIE-LYNN*	Fishing
9/3/2020	Kauai	41444	N21° 52.635'	W159° 35.545'	S10	*YUKIE-LYNN*	Fishing
9/3/2020	Kauai	41449	N21° 52.640'	W159° 34.093'	S10	*YUKIE-LYNN*	Fishing
9/3/2020	Kauai	41278	N21° 52.106'	W159° 31.478'	S10	*YUKIE-LYNN*	Fishing
9/3/2020	Kauai	41133	N21° 51.567'	W159° 30.605'	S21	*YUKIE-LYNN*	Fishing
9/3/2020	Kauai	41488	N21° 52.673'	W159° 22.478'	S16	*YUKIE-LYNN*	Fishing
9/3/2020	Kauai	41869	N21° 54.031'	W159° 21.320'	S16	*YUKIE-LYNN*	Fishing
9/3/2020	Kauai	42030	N21° 54.844'	W159° 21.031'	S14	*YUKIE-LYNN*	Fishing
9/3/2020	Kauai	42031	N21° 54.845'	W159° 20.741'	S20	*YUKIE-LYNN*	Fishing
9/3/2020	Kauai	42125	N21° 55.388'	W159° 20.452'	S15	*YUKIE-LYNN*	Fishing
9/4/2020	Kauai	43457	N22° 2.439'	W159° 18.143'	S10	*YUKIE-LYNN*	Fishing
9/4/2020	Kauai	43569	N22° 3.254'	W159° 17.272'	S16	*YUKIE-LYNN*	Fishing
9/4/2020	Kauai	43598	N22° 3.524'	W159° 17.563'	S10	*YUKIE-LYNN*	Fishing
9/4/2020	Kauai	43691	N22° 4.609'	W159° 16.984'	S15	*YUKIE-LYNN*	Fishing
9/4/2020	Kauai	44013	N22° 7.863'	W159° 16.118'	S11	*YUKIE-LYNN*	Fishing
9/4/2020	Kauai	44105	N22° 8.677'	W159° 15.538'	S16	*YUKIE-LYNN*	Fishing
9/4/2020	Kauai	44486	N22° 11.385'	W159° 17.289'	S13	*YUKIE-LYNN*	Fishing
9/4/2020	Kauai	44698	N22° 12.738'	W159° 18.165'	S03	*YUKIE-LYNN*	Fishing
9/4/2020	Kauai	45141	N22° 14.630'	W159° 21.080'	S06	*YUKIE-LYNN*	Fishing
9/4/2020	Kauai	45272	N22° 15.172'	W159° 20.790'	S22	*YUKIE-LYNN*	Fishing
9/4/2020	Kauai	45271	N22° 15.172'	W159° 21.081'	S22	*YUKIE-LYNN*	Fishing
9/5/2020	Kauai	45250	N22° 15.156'	W159° 27.196'	S14	*YUKIE-LYNN*	Fishing
9/5/2020	Kauai	45246	N22° 15.153'	W159° 28.360'	S01	*YUKIE-LYNN*	Fishing
9/5/2020	Kauai	45364	N22° 15.694'	W159° 28.653'	S13	*YUKIE-LYNN*	Fishing
9/5/2020	Kauai	45485	N22° 16.774'	W159° 30.113'	S23	*YUKIE-LYNN*	Fishing
9/5/2020	Kauai	45426	N22° 16.229'	W159° 30.984'	S17	*YUKIE-LYNN*	Fishing
9/5/2020	Kauai	45298	N22° 15.416'	W159° 30.982'	S02	*YUKIE-LYNN*	Fishing
9/5/2020	Kauai	45499	N22° 17.036'	W159° 33.026'	S13	*YUKIE-LYNN*	Fishing
9/5/2020	Kauai	45474	N22° 16.764'	W159° 33.316'	S05	*YUKIE-LYNN*	Fishing
9/5/2020	Kauai	45438	N22° 16.483'	W159° 35.936'	S16	*YUKIE-LYNN*	Fishing
9/5/2020	Kauai	45281	N22° 15.399'	W159° 35.931'	S01	*YUKIE-LYNN*	Fishing
9/6/2020	Kauai	44586	N22° 12.116'	W159° 43.484'	S09	*YUKIE-LYNN*	Fishing
9/6/2020	Kauai	44621	N22° 12.386'	W159° 43.777'	S22	*YUKIE-LYNN*	Fishing
9/6/2020	Kauai	44582	N22° 12.111'	W159° 44.648'	S23	*YUKIE-LYNN*	Fishing
9/6/2020	Kauai	44495	N22° 11.565'	W159° 45.518'	S17	*YUKIE-LYNN*	Fishing
9/6/2020	Kauai	44366	N22° 10.745'	W159° 46.969'	S13	*YUKIE-LYNN*	Fishing
9/6/2020	Kauai	44080	N22° 8.570'	W159° 48.412'	S06	*YUKIE-LYNN*	Fishing
9/6/2020	Kauai	43990	N22° 7.755'	W159° 48.698'	S05	*YUKIE-LYNN*	Fishing
9/6/2020	Kauai	43698	N22° 4.773'	W159° 48.971'	S07	*YUKIE-LYNN*	Fishing
9/6/2020	Kauai	43605	N22° 3.683'	W159° 50.128'	S24	*YUKIE-LYNN*	Fishing
9/6/2020	Kauai	43135	N22° 0.434'	W159° 49.528'	S24	*YUKIE-LYNN*	Fishing
9/6/2020	Kauai	42996	N21° 59.628'	W159° 48.070'	S09	*YUKIE-LYNN*	Fishing
9/6/2020	Kauai	42591	N21° 57.471'	W159° 45.734'	S10	*YUKIE-LYNN*	Fishing
9/12/2020	Niʻihau	43463	N22° 2.501'	W160° 6.691'	S22	*YUKIE-LYNN*	Fishing
9/12/2020	Niʻihau	43109	N22° 0.315'	W160° 9.289'	S22	*YUKIE-LYNN*	Fishing
9/12/2020	Niʻihau	43058	N22° 0.037'	W160° 10.159'	S24	*YUKIE-LYNN*	Fishing
9/12/2020	Niʻihau	43017	N21° 59.771'	W160° 9.575'	S16	*YUKIE-LYNN*	Fishing
9/12/2020	Niʻihau	42851	N21° 58.683'	W160° 10.148'	S14	*YUKIE-LYNN*	Fishing
9/12/2020	Niʻihau	42799	N21° 58.409'	W160° 10.436'	S01	*YUKIE-LYNN*	Fishing
9/12/2020	Niʻihau	42849	N21° 58.678'	W160° 10.729'	S20	*YUKIE-LYNN*	Fishing
9/12/2020	Niʻihau	42742	N21° 58.126'	W160° 12.177'	S17	*YUKIE-LYNN*	Fishing
9/12/2020	Niʻihau	42690	N21° 57.855'	W160° 12.174'	S07	*YUKIE-LYNN*	Fishing
9/12/2020	Niʻihau	42133	N21° 55.399'	W160° 14.477'	S13	*YUKIE-LYNN*	Fishing
9/12/2020	Niʻihau	42181	N21° 55.668'	W160° 14.770'	S21	*YUKIE-LYNN*	Fishing
9/13/2020	Niʻihau	41986	N21° 54.582'	W160° 15.051'	S13	*YUKIE-LYNN*	Fishing
9/13/2020	Niʻihau	41669	N21° 53.220'	W160° 15.910'	S01	*YUKIE-LYNN*	Fishing

SAMPLE_DATE	Island	PSU	lat_deg	lon_deg	STRATA_2020	VESSEL	GEAR
9/13/2020	Niʻihau	41583	N21° 52.947'	W160° 16.198'	S22	*YUKIE-LYNN*	Fishing
9/13/2020	Niʻihau	41035	N21° 51.052'	W160° 15.891'	S22	*YUKIE-LYNN*	Fishing
9/13/2020	Niʻihau	40984	N21° 50.781'	W160° 15.889'	S10	*YUKIE-LYNN*	Fishing
9/13/2020	Niʻihau	39862	N21° 44.302'	W160° 12.641'	S12	*YUKIE-LYNN*	Fishing
9/13/2020	Niʻihau	40059	N21° 45.121'	W160° 11.778'	S14	*YUKIE-LYNN*	Fishing
9/13/2020	Niʻihau	40302	N21° 46.211'	W160° 10.916'	S14	*YUKIE-LYNN*	Fishing
9/13/2020	Niʻihau	40746	N21° 48.931'	W160° 9.488'	S10	*YUKIE-LYNN*	Fishing
9/13/2020	Niʻihau	40786	N21° 49.212'	W160° 8.039'	S17	*YUKIE-LYNN*	Fishing
9/16/2020	Niʻihau	41611	N21° 53.048'	W160° 1.681'	S05	*YUKIE-LYNN*	Fishing
9/16/2020	Niʻihau	41191	N21° 51.682'	W160° 3.413'	S10	*YUKIE-LYNN*	Fishing
9/16/2020	Niʻihau	40966	N21° 50.585'	W160° 5.437'	S14	*YUKIE-LYNN*	Fishing
9/16/2020	Niʻihau	40828	N21° 49.499'	W160° 5.719'	S24	*YUKIE-LYNN*	Fishing
9/16/2020	Niʻihau	40576	N21° 47.596'	W160° 6.575'	S21	*YUKIE-LYNN*	Fishing
9/16/2020	Niʻihau	40655	N21° 48.150'	W160° 4.838'	S22	*YUKIE-LYNN*	Fishing
9/16/2020	Niʻihau	40834	N21° 49.510'	W160° 3.978'	S22	*YUKIE-LYNN*	Fishing
8/17/2020	Maui Nui	24503	N20° 59.957'	W156° 20.821'	S05	*NAOMI K*	Fishing
8/17/2020	Maui Nui	23677	N20° 59.202'	W156° 24.583'	S08	*NAOMI K*	Fishing
8/17/2020	Maui Nui	23408	N20° 58.962'	W156° 26.606'	S09	*NAOMI K*	Fishing
8/17/2020	Maui Nui	24481	N21° 0.054'	W156° 27.165'	S06	*NAOMI K*	Fishing
8/17/2020	Maui Nui	24195	N20° 59.822'	W156° 29.765'	S06	*NAOMI K*	Fishing
8/18/2020	Maui Nui	22442	N20° 57.657'	W156° 12.499'	S10	*NAOMI K*	Fishing
8/18/2020	Maui Nui	23460	N20° 58.726'	W156° 11.614'	S24	*NAOMI K*	Fishing
8/18/2020	Maui Nui	23982	N20° 59.291'	W156° 13.046'	S20	*NAOMI K*	Fishing
8/18/2020	Maui Nui	22688	N20° 57.942'	W156° 13.359'	S10	*NAOMI K*	Fishing
8/18/2020	Maui Nui	22687	N20° 57.947'	W156° 13.647'	S10	*NAOMI K*	Fishing
8/18/2020	Maui Nui	22683	N20° 57.965'	W156° 14.800'	S10	*NAOMI K*	Fishing
8/18/2020	Maui Nui	23446	N20° 58.792'	W156° 15.650'	S10	*NAOMI K*	Fishing
8/18/2020	Maui Nui	23706	N20° 59.072'	W156° 16.222'	S10	*NAOMI K*	Fishing
8/18/2020	Maui Nui	23705	N20° 59.076'	W156° 16.510'	S10	*NAOMI K*	Fishing
8/18/2020	Maui Nui	23184	N20° 58.544'	W156° 17.097'	S07	*NAOMI K*	Fishing
8/19/2020	Maui Nui	14335	N20° 40.598'	W156° 30.370'	S07	*NAOMI K*	Fishing
8/19/2020	Maui Nui	14333	N20° 40.606'	W156° 30.946'	S10	*NAOMI K*	Fishing
8/19/2020	Maui Nui	14974	N20° 41.952'	W156° 30.348'	S03	*NAOMI K*	Fishing
8/19/2020	Maui Nui	14969	N20° 41.973'	W156° 31.787'	S10	*NAOMI K*	Fishing
8/19/2020	Maui Nui	15101	N20° 42.235'	W156° 31.207'	S11	*NAOMI K*	Fishing
8/19/2020	Maui Nui	15361	N20° 42.781'	W156° 31.486'	S02	*NAOMI K*	Fishing
8/19/2020	Maui Nui	15226	N20° 42.527'	W156° 32.642'	S02	*NAOMI K*	Fishing
8/19/2020	Maui Nui	14442	N20° 40.938'	W156° 35.258'	S15	*NAOMI K*	Fishing
8/19/2020	Maui Nui	15218	N20° 42.559'	W156° 34.945'	S10	*NAOMI K*	Fishing
8/19/2020	Maui Nui	15742	N20° 43.639'	W156° 34.639'	S02	*NAOMI K*	Fishing
8/20/2020	Maui Nui	14023	N20° 40.328'	W156° 50.524'	S21	*NAOMI K*	Fishing
8/20/2020	Maui Nui	13538	N20° 39.255'	W156° 51.403'	S24	*NAOMI K*	Fishing
8/20/2020	Maui Nui	13528	N20° 39.291'	W156° 54.281'	S24	*NAOMI K*	Fishing
8/20/2020	Maui Nui	13896	N20° 40.093'	W156° 53.406'	S24	*NAOMI K*	Fishing
8/20/2020	Maui Nui	14012	N20° 40.367'	W156° 53.691'	S24	*NAOMI K*	Fishing
8/20/2020	Maui Nui	14506	N20° 41.440'	W156° 52.812'	S22	*NAOMI K*	Fishing
8/20/2020	Maui Nui	14636	N20° 41.708'	W156° 52.520'	S22	*NAOMI K*	Fishing
8/20/2020	Maui Nui	14634	N20° 41.715'	W156° 53.096'	S22	*NAOMI K*	Fishing
8/20/2020	Maui Nui	14763	N20° 41.993'	W156° 53.668'	S22	*NAOMI K*	Fishing
8/20/2020	Maui Nui	15152	N20° 42.809'	W156° 53.945'	S07	*NAOMI K*	Fishing
8/22/2020	Maui Nui	27425	N21° 2.859'	W156° 33.753'	S05	*NAOMI K*	Fishing
8/22/2020	Maui Nui	28543	N21° 3.975'	W156° 36.044'	S13	*NAOMI K*	Fishing
8/22/2020	Maui Nui	29045	N21° 4.533'	W156° 37.190'	S18	*NAOMI K*	Fishing
8/22/2020	Maui Nui	28267	N21° 3.741'	W156° 38.645'	S16	*NAOMI K*	Fishing
8/22/2020	Maui Nui	27699	N21° 3.219'	W156° 40.096'	S16	*NAOMI K*	Fishing
8/22/2020	Maui Nui	27401	N21° 2.956'	W156° 40.678'	S22	*NAOMI K*	Fishing
8/22/2020	Maui Nui	28781	N21° 4.318'	W156° 41.234'	S22	*NAOMI K*	Fishing
8/22/2020	Maui Nui	29711	N21° 5.398'	W156° 40.928'	S18	*NAOMI K*	Fishing
8/23/2020	Maui Nui	16222	N20° 44.742'	W156° 36.062'	S03	*NAOMI K*	Fishing
8/23/2020	Maui Nui	15736	N20° 43.663'	W156° 36.367'	S10	*NAOMI K*	Fishing
8/23/2020	Maui Nui	15602	N20° 43.408'	W156° 37.523'	S11	*NAOMI K*	Fishing
8/23/2020	Maui Nui	15339	N20° 42.870'	W156° 37.819'	S10	*NAOMI K*	Fishing
8/23/2020	Maui Nui	15467	N20° 43.153'	W156° 38.678'	S10	*NAOMI K*	Fishing
8/23/2020	Maui Nui	15198	N20° 42.639'	W156° 40.702'	S20	*NAOMI K*	Fishing
8/23/2020	Maui Nui	15724	N20° 43.710'	W156° 39.821'	S14	*NAOMI K*	Fishing
8/23/2020	Maui Nui	16318	N20° 45.057'	W156° 39.225'	S11	*NAOMI K*	Fishing
8/23/2020	Maui Nui	16622	N20° 45.885'	W156° 40.364'	S04	*NAOMI K*	Fishing
8/23/2020	Maui Nui	16819	N20° 46.431'	W156° 40.644'	S10	*NAOMI K*	Fishing
8/24/2020	Maui Nui	17006	N20° 47.007'	W156° 43.228'	S01	*NAOMI K*	Fishing

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8/24/2020	Maui Nui	16190	N20° 44.867'	W156° 45.276'	S07	*NAOMI K*	Fishing
8/24/2020	Maui Nui	16076	N20° 44.607'	W156° 46.144'	S07	*NAOMI K*	Fishing
8/24/2020	Maui Nui	16068	N20° 44.637'	W156° 48.447'	S08	*NAOMI K*	Fishing
8/24/2020	Maui Nui	15951	N20° 44.370'	W156° 48.739'	S14	*NAOMI K*	Fishing
8/24/2020	Maui Nui	15169	N20° 42.748'	W156° 49.050'	S20	*NAOMI K*	Fishing
8/24/2020	Maui Nui	15032	N20° 42.502'	W156° 51.070'	S22	*NAOMI K*	Fishing
8/24/2020	Maui Nui	14516	N20° 41.404'	W156° 49.933'	S21	*NAOMI K*	Fishing
8/24/2020	Maui Nui	15174	N20° 42.730'	W156° 47.611'	S17	*NAOMI K*	Fishing
8/26/2020	Maui Nui	12805	N20° 37.437'	W156° 36.752'	S02	*NAOMI K*	Fishing
8/26/2020	Maui Nui	12546	N20° 36.916'	W156° 38.199'	S07	*NAOMI K*	Fishing
8/26/2020	Maui Nui	12541	N20° 36.935'	W156° 39.637'	S13	*NAOMI K*	Fishing
8/26/2020	Maui Nui	13207	N20° 38.282'	W156° 39.041'	S20	*NAOMI K*	Fishing
8/26/2020	Maui Nui	13446	N20° 38.870'	W156° 42.486'	S22	*NAOMI K*	Fishing
8/26/2020	Maui Nui	14172	N20° 40.491'	W156° 42.174'	S22	*NAOMI K*	Fishing
8/26/2020	Maui Nui	14293	N20° 40.766'	W156° 42.457'	S22	*NAOMI K*	Fishing
8/26/2020	Maui Nui	14798	N20° 41.864'	W156° 43.593'	S11	*NAOMI K*	Fishing
8/27/2020	Maui Nui	11622	N20° 34.856'	W156° 46.286'	S24	*NAOMI K*	Fishing
8/27/2020	Maui Nui	11728	N20° 35.100'	W156° 44.268'	S22	*NAOMI K*	Fishing
8/27/2020	Maui Nui	11832	N20° 35.371'	W156° 44.264'	S19	*NAOMI K*	Fishing
8/27/2020	Maui Nui	11834	N20° 35.364'	W156° 43.689'	S21	*NAOMI K*	Fishing
8/27/2020	Maui Nui	11837	N20° 35.352'	W156° 42.826'	S22	*NAOMI K*	Fishing
8/27/2020	Maui Nui	12058	N20° 35.894'	W156° 42.818'	S22	*NAOMI K*	Fishing
8/27/2020	Maui Nui	12059	N20° 35.890'	W156° 42.530'	S22	*NAOMI K*	Fishing
8/28/2020	Maui Nui	29731	N21° 5.317'	W156° 35.157'	S17	*NAOMI K*	Fishing
8/28/2020	Maui Nui	30261	N21° 6.457'	W156° 39.180'	S22	*NAOMI K*	Fishing
8/28/2020	Maui Nui	30260	N21° 6.461'	W156° 39.468'	S19	*NAOMI K*	Fishing
8/28/2020	Maui Nui	31510	N21° 10.225'	W156° 37.387'	S23	*NAOMI K*	Fishing
8/28/2020	Maui Nui	32309	N21° 11.866'	W156° 38.517'	S19	*NAOMI K*	Fishing
8/28/2020	Maui Nui	32156	N21° 11.611'	W156° 39.676'	S22	*NAOMI K*	Fishing
8/28/2020	Maui Nui	32921	N21° 12.985'	W156° 41.099'	S24	*NAOMI K*	Fishing
8/28/2020	Maui Nui	32120	N21° 11.750'	W156° 50.073'	S08	*NAOMI K*	Fishing
8/28/2020	Maui Nui	31833	N21° 11.237'	W156° 52.392'	S04	*NAOMI K*	Fishing
8/28/2020	Maui Nui	31998	N21° 11.396'	W156° 43.723'	S01	*NAOMI K*	Fishing
8/28/2020	Maui Nui	31388	N21° 9.994'	W156° 40.279'	S05	*NAOMI K*	Fishing
9/1/2020	Maui Nui	21220	N20° 56.294'	W156° 11.948'	S10	*NAOMI K*	Fishing
9/1/2020	Maui Nui	20797	N20° 55.714'	W156° 9.653'	S20	*NAOMI K*	Fishing
9/1/2020	Maui Nui	19839	N20° 54.365'	W156° 9.966'	S10	*NAOMI K*	Fishing
9/2/2020	Maui Nui	13242	N20° 38.140'	W156° 28.971'	S05	*NAOMI K*	Fishing
9/2/2020	Maui Nui	12101	N20° 35.694'	W156° 28.436'	S21	*NAOMI K*	Fishing
9/2/2020	Maui Nui	11571	N20° 34.336'	W156° 28.171'	S20	*NAOMI K*	Fishing
9/2/2020	Maui Nui	11574	N20° 34.323'	W156° 27.308'	S22	*NAOMI K*	Fishing
9/2/2020	Maui Nui	11283	N20° 33.519'	W156° 27.897'	S22	*NAOMI K*	Fishing
9/2/2020	Maui Nui	10882	N20° 31.902'	W156° 28.499'	S22	*NAOMI K*	Fishing
9/2/2020	Maui Nui	10930	N20° 32.182'	W156° 29.069'	S22	*NAOMI K*	Fishing
9/2/2020	Maui Nui	11565	N20° 34.361'	W156° 29.896'	S20	*NAOMI K*	Fishing
9/2/2020	Maui Nui	13223	N20° 38.218'	W156° 34.438'	S10	*NAOMI K*	Fishing
9/3/2020	Maui Nui	14307	N20° 40.711'	W156° 38.428'	S15	*NAOMI K*	Fishing
9/3/2020	Maui Nui	12537	N20° 36.951'	W156° 40.788'	S20	*NAOMI K*	Fishing
9/3/2020	Maui Nui	12660	N20° 37.229'	W156° 41.359'	S20	*NAOMI K*	Fishing
9/3/2020	Maui Nui	12170	N20° 36.176'	W156° 43.677'	S22	*NAOMI K*	Fishing
9/3/2020	Maui Nui	12914	N20° 37.798'	W156° 43.365'	S19	*NAOMI K*	Fishing
9/3/2020	Maui Nui	15969	N20° 44.302'	W156° 43.556'	S02	*NAOMI K*	Fishing
9/4/2020	Maui Nui	10357	N20° 29.683'	W156° 44.348'	S05	*NAOMI K*	Fishing
9/4/2020	Maui Nui	10244	N20° 28.893'	W156° 46.085'	S24	*NAOMI K*	Fishing
9/4/2020	Maui Nui	10399	N20° 29.972'	W156° 45.782'	S09	*NAOMI K*	Fishing
9/4/2020	Maui Nui	10752	N20° 31.612'	W156° 46.908'	S11	*NAOMI K*	Fishing
9/4/2020	Maui Nui	10494	N20° 30.562'	W156° 49.511'	S24	*NAOMI K*	Fishing
9/4/2020	Maui Nui	10845	N20° 32.176'	W156° 48.626'	S22	*NAOMI K*	Fishing
9/4/2020	Maui Nui	12267	N20° 36.532'	W156° 50.290'	S24	*NAOMI K*	Fishing
9/4/2020	Maui Nui	14403	N20° 41.089'	W156° 46.483'	S21	*NAOMI K*	Fishing
8/15/2020	Big Island	18	N18° 51.466'	W155° 41.132'	S12	*AO SHIBI IV*	Fishing
8/15/2020	Big Island	37	N18° 52.278'	W155° 41.116'	S10	*AO SHIBI IV*	Fishing
8/15/2020	Big Island	50	N18° 52.523'	W155° 39.689'	S22	*AO SHIBI IV*	Fishing
8/15/2020	Big Island	101	N18° 53.876'	W155° 39.663'	S01	*AO SHIBI IV*	Fishing
8/15/2020	Big Island	132	N18° 54.397'	W155° 38.514'	S10	*AO SHIBI IV*	Fishing
8/17/2020	Big Island	538	N19° 2.147'	W155° 32.950'	S21	*AO SHIBI IV*	Fishing
8/17/2020	Big Island	575	N19° 3.213'	W155° 32.073'	S24	*AO SHIBI IV*	Fishing
8/17/2020	Big Island	628	N19° 4.566'	W155° 32.045'	S20	*AO SHIBI IV*	Fishing
8/17/2020	Big Island	700	N19° 6.704'	W155° 30.577'	S22	*AO SHIBI IV*	Fishing

SAMPLE_DATE	Island	PSU	lat_deg	lon_deg	STRATA_2020	VESSEL	GEAR
8/17/2020	Big Island	1249	N19° 15.482'	W155° 9.300'	S10	*AO SHIBI IV*	Fishing
8/17/2020	Big Island	1335	N19° 16.257'	W155° 7.572'	S10	*AO SHIBI IV*	Fishing
8/17/2020	Big Island	1387	N19° 17.567'	W155° 5.546'	S12	*AO SHIBI IV*	Fishing
8/17/2020	Big Island	1484	N19° 19.626'	W155° 0.651'	S22	*AO SHIBI IV*	Fishing
8/18/2020	Big Island	2416	N19° 38.217'	W154° 57.053'	S11	*AO SHIBI IV*	Fishing
8/18/2020	Big Island	2265	N19° 35.468'	W154° 55.123'	S21	*AO SHIBI IV*	Fishing
8/18/2020	Big Island	2183	N19° 34.070'	W154° 53.160'	S22	*AO SHIBI IV*	Fishing
8/18/2020	Big Island	2165	N19° 33.793'	W154° 52.882'	S16	*AO SHIBI IV*	Fishing
8/18/2020	Big Island	2055	N19° 32.046'	W154° 47.504'	S24	*AO SHIBI IV*	Fishing
8/18/2020	Big Island	1947	N19° 30.166'	W154° 48.124'	S16	*AO SHIBI IV*	Fishing
8/18/2020	Big Island	1905	N19° 29.362'	W154° 48.430'	S12	*AO SHIBI IV*	Fishing
8/18/2020	Big Island	1510	N19° 20.136'	W154° 59.213'	S22	*AO SHIBI IV*	Fishing
8/18/2020	Big Island	1496	N19° 19.884'	W155° 0.074'	S16	*AO SHIBI IV*	Fishing
8/19/2020	Big Island	2524	N19° 40.400'	W154° 57.855'	S04	*AO SHIBI IV*	Fishing
8/19/2020	Big Island	2673	N19° 43.671'	W154° 58.916'	S03	*AO SHIBI IV*	Fishing
8/19/2020	Big Island	2895	N19° 45.281'	W154° 58.304'	S22	*AO SHIBI IV*	Fishing
8/19/2020	Big Island	2937	N19° 45.551'	W154° 58.297'	S22	*AO SHIBI IV*	Fishing
8/19/2020	Big Island	3028	N19° 46.098'	W154° 58.569'	S22	*AO SHIBI IV*	Fishing
8/19/2020	Big Island	3027	N19° 46.105'	W154° 58.855'	S22	*AO SHIBI IV*	Fishing
8/19/2020	Big Island	3025	N19° 46.118'	W154° 59.426'	S22	*AO SHIBI IV*	Fishing
8/19/2020	Big Island	2931	N19° 45.589'	W155° 0.011'	S02	*AO SHIBI IV*	Fishing
8/19/2020	Big Island	3175	N19° 46.961'	W155° 0.834'	S21	*AO SHIBI IV*	Fishing
8/19/2020	Big Island	3226	N19° 47.263'	W155° 2.256'	S10	*AO SHIBI IV*	Fishing
8/19/2020	Big Island	3506	N19° 48.660'	W155° 4.223'	S10	*AO SHIBI IV*	Fishing
8/19/2020	Big Island	3631	N19° 49.201'	W155° 4.210'	S10	*AO SHIBI IV*	Fishing
8/19/2020	Big Island	3516	N19° 48.596'	W155° 1.365'	S20	*AO SHIBI IV*	Fishing
8/20/2020	Big Island	5366	N19° 55.544'	W154° 57.472'	S24	*AO SHIBI IV*	Fishing
8/20/2020	Big Island	4845	N19° 53.670'	W154° 58.378'	S24	*AO SHIBI IV*	Fishing
8/20/2020	Big Island	4693	N19° 53.149'	W154° 59.249'	S24	*AO SHIBI IV*	Fishing
8/20/2020	Big Island	4062	N19° 50.676'	W154° 57.596'	S24	*AO SHIBI IV*	Fishing
8/20/2020	Big Island	3656	N19° 49.041'	W154° 57.066'	S24	*AO SHIBI IV*	Fishing
8/20/2020	Big Island	3580	N19° 48.854'	W155° 0.787'	S20	*AO SHIBI IV*	Fishing
8/20/2020	Big Island	4047	N19° 50.773'	W155° 1.883'	S20	*AO SHIBI IV*	Fishing
8/20/2020	Big Island	4321	N19° 51.861'	W155° 2.142'	S21	*AO SHIBI IV*	Fishing
8/20/2020	Big Island	4604	N19° 52.974'	W155° 3.545'	S20	*AO SHIBI IV*	Fishing
8/20/2020	Big Island	4896	N19° 54.107'	W155° 5.805'	S07	*AO SHIBI IV*	Fishing
8/20/2020	Big Island	5675	N19° 57.169'	W155° 9.737'	S07	*AO SHIBI IV*	Fishing
8/20/2020	Big Island	5819	N19° 57.729'	W155° 10.582'	S02	*AO SHIBI IV*	Fishing
8/21/2020	Big Island	5703	N19° 56.993'	W155° 1.728'	S24	*AO SHIBI IV*	Fishing
8/21/2020	Big Island	5851	N19° 57.527'	W155° 1.428'	S24	*AO SHIBI IV*	Fishing
8/21/2020	Big Island	6042	N19° 58.390'	W155° 3.696'	S24	*AO SHIBI IV*	Fishing
8/21/2020	Big Island	6231	N19° 59.220'	W155° 4.534'	S23	*AO SHIBI IV*	Fishing
8/21/2020	Big Island	5906	N19° 57.887'	W155° 5.426'	S20	*AO SHIBI IV*	Fishing
8/21/2020	Big Island	6520	N20° 0.655'	W155° 8.221'	S24	*AO SHIBI IV*	Fishing
8/21/2020	Big Island	6698	N20° 1.939'	W155° 17.639'	#N/A	*AO SHIBI IV*	Fishing
8/21/2020	Big Island	7153	N20° 4.415'	W155° 19.587'	S20	*AO SHIBI IV*	Fishing
8/21/2020	Big Island	7425	N20° 5.810'	W155° 21.560'	S20	*AO SHIBI IV*	Fishing
8/21/2020	Big Island	7484	N20° 6.080'	W155° 21.553'	S20	*AO SHIBI IV*	Fishing
8/21/2020	Big Island	7680	N20° 6.892'	W155° 21.535'	S20	*AO SHIBI IV*	Fishing
8/21/2020	Big Island	7477	N20° 6.122'	W155° 23.558'	S20	*AO SHIBI IV*	Fishing
8/22/2020	Big Island	8554	N20° 10.227'	W155° 25.757'	S24	*AO SHIBI IV*	Fishing
8/22/2020	Big Island	8414	N20° 9.680'	W155° 25.483'	S24	*AO SHIBI IV*	Fishing
8/22/2020	Big Island	8415	N20° 9.674'	W155° 25.196'	S24	*AO SHIBI IV*	Fishing
8/22/2020	Big Island	8338	N20° 9.444'	W155° 27.208'	S24	*AO SHIBI IV*	Fishing
8/22/2020	Big Island	7744	N20° 7.221'	W155° 24.393'	S20	*AO SHIBI IV*	Fishing
8/22/2020	Big Island	7812	N20° 7.550'	W155° 27.251'	S20	*AO SHIBI IV*	Fishing
8/22/2020	Big Island	7655	N20° 7.038'	W155° 28.696'	S10	*AO SHIBI IV*	Fishing
9/26/2020	Maui Nui	11211	N20° 33.171'	W156° 22.726'	S10	*AO SHIBI IV*	Fishing
9/26/2020	Maui Nui	11307	N20° 33.416'	W156° 20.996'	S10	*AO SHIBI IV*	Fishing
9/26/2020	Maui Nui	11408	N20° 33.660'	W156° 19.267'	S14	*AO SHIBI IV*	Fishing
9/26/2020	Maui Nui	11411	N20° 33.646'	W156° 18.404'	S10	*AO SHIBI IV*	Fishing
9/26/2020	Maui Nui	11415	N20° 33.628'	W156° 17.254'	S10	*AO SHIBI IV*	Fishing
9/26/2020	Maui Nui	12135	N20° 35.432'	W156° 11.470'	S21	*AO SHIBI IV*	Fishing
9/26/2020	Maui Nui	12370	N20° 35.974'	W156° 11.460'	S10	*AO SHIBI IV*	Fishing
9/26/2020	Maui Nui	12371	N20° 35.969'	W156° 11.172'	S14	*AO SHIBI IV*	Fishing
9/26/2020	Maui Nui	12258	N20° 35.675'	W156° 9.739'	S10	*AO SHIBI IV*	Fishing
9/26/2020	Maui Nui	14115	N20° 39.585'	W156° 0.747'	S10	*AO SHIBI IV*	Fishing
9/26/2020	Maui Nui	14237	N20° 39.841'	W155° 59.879'	S16	*AO SHIBI IV*	Fishing
9/27/2020	Maui Nui	17688	N20° 48.513'	W156° 0.284'	S22	*AO SHIBI IV*	Fishing

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9/27/2020	Maui Nui	17244	N20° 46.854'	W155° 58.301'	S02	*AO SHIBI IV*	Fishing
9/27/2020	Maui Nui	16674	N20° 45.209'	W155° 57.182'	S10	*AO SHIBI IV*	Fishing
9/27/2020	Maui Nui	15907	N20° 43.314'	W155° 57.220'	S15	*AO SHIBI IV*	Fishing
9/27/2020	Maui Nui	15255	N20° 41.971'	W155° 57.823'	S11	*AO SHIBI IV*	Fishing
8/22/2020	Big Island	304	N18° 57.747'	W155° 44.139'	S22	*RIDE ON*	Fishing
8/22/2020	Big Island	323	N18° 58.018'	W155° 44.134'	S16	*RIDE ON*	Fishing
8/22/2020	Big Island	422	N19° 0.258'	W155° 48.360'	S22	*RIDE ON*	Fishing
8/22/2020	Big Island	435	N19° 0.548'	W155° 49.494'	S22	*RIDE ON*	Fishing
8/22/2020	Big Island	541	N19° 2.777'	W155° 53.153'	S16	*RIDE ON*	Fishing
8/22/2020	Big Island	611	N19° 4.696'	W155° 54.542'	S16	*RIDE ON*	Fishing
8/22/2020	Big Island	1704	N19° 26.378'	W155° 55.562'	S10	*RIDE ON*	Fishing
8/22/2020	Big Island	1765	N19° 28.017'	W155° 56.388'	S15	*RIDE ON*	Fishing
8/22/2020	Big Island	2420	N19° 39.759'	W156° 2.169'	S22	*RIDE ON*	Fishing
8/23/2020	Big Island	8702	N20° 11.602'	W155° 55.550'	S10	*RIDE ON*	Fishing
8/23/2020	Big Island	8567	N20° 11.056'	W155° 55.274'	S10	*RIDE ON*	Fishing
8/23/2020	Big Island	8493	N20° 10.805'	W155° 56.426'	S19	*RIDE ON*	Fishing
8/23/2020	Big Island	8358	N20° 10.254'	W155° 55.864'	S15	*RIDE ON*	Fishing
8/23/2020	Big Island	7129	N20° 5.075'	W155° 53.958'	S14	*RIDE ON*	Fishing
8/23/2020	Big Island	6923	N20° 3.988'	W155° 53.693'	S17	*RIDE ON*	Fishing
8/23/2020	Big Island	6416	N20° 1.296'	W155° 54.606'	S24	*RIDE ON*	Fishing
8/23/2020	Big Island	6245	N20° 0.453'	W155° 52.903'	S22	*RIDE ON*	Fishing
8/23/2020	Big Island	6310	N20° 0.704'	W155° 51.752'	S09	*RIDE ON*	Fishing
8/23/2020	Big Island	5809	N19° 58.528'	W155° 51.223'	S03	*RIDE ON*	Fishing
8/23/2020	Big Island	5584	N19° 57.791'	W155° 55.533'	S08	*RIDE ON*	Fishing
8/23/2020	Big Island	5445	N19° 57.245'	W155° 55.257'	S08	*RIDE ON*	Fishing
8/23/2020	Big Island	5379	N19° 56.974'	W155° 55.263'	S06	*RIDE ON*	Fishing
8/30/2020	Big Island	5033	N19° 55.616'	W155° 55.003'	S04	*RIDE ON*	Fishing
8/30/2020	Big Island	5102	N19° 55.916'	W155° 56.715'	S06	*RIDE ON*	Fishing
8/30/2020	Big Island	5242	N19° 56.467'	W155° 57.277'	S21	*RIDE ON*	Fishing
8/30/2020	Big Island	4722	N19° 54.587'	W155° 58.172'	S05	*RIDE ON*	Fishing
8/30/2020	Big Island	4507	N19° 53.770'	W155° 57.901'	S08	*RIDE ON*	Fishing
8/30/2020	Big Island	4359	N19° 53.263'	W155° 59.915'	S05	*RIDE ON*	Fishing
8/30/2020	Big Island	4022	N19° 51.890'	W155° 58.796'	S01	*RIDE ON*	Fishing
8/30/2020	Big Island	4076	N19° 52.237'	W156° 3.369'	S11	*RIDE ON*	Fishing
8/30/2020	Big Island	3487	N19° 49.800'	W156° 3.414'	S09	*RIDE ON*	Fishing
8/30/2020	Big Island	3037	N19° 47.681'	W156° 6.315'	S10	*RIDE ON*	Fishing
8/30/2020	Big Island	2743	N19° 45.767'	W156° 5.205'	S05	*RIDE ON*	Fishing
8/30/2020	Big Island	2559	N19° 42.765'	W156° 3.830'	S24	*RIDE ON*	Fishing
10/18/2020	Big Island	9949	N20° 18.564'	W155° 51.108'	S22	*RIDE ON*	Fishing
10/18/2020	Big Island	10008	N20° 18.840'	W155° 51.389'	S19	*RIDE ON*	Fishing
10/18/2020	Big Island	9945	N20° 18.585'	W155° 52.255'	S18	*RIDE ON*	Fishing
10/18/2020	Big Island	9827	N20° 18.038'	W155° 51.979'	S16	*RIDE ON*	Fishing
10/18/2020	Big Island	9649	N20° 17.226'	W155° 51.996'	S11	*RIDE ON*	Fishing
10/18/2020	Big Island	9707	N20° 17.507'	W155° 52.564'	S10	*RIDE ON*	Fishing
10/18/2020	Big Island	9880	N20° 18.339'	W155° 53.695'	S18	*RIDE ON*	Fishing
10/18/2020	Big Island	9873	N20° 18.375'	W155° 55.704'	S22	*RIDE ON*	Fishing
10/18/2020	Big Island	9571	N20° 17.041'	W155° 56.878'	S24	*RIDE ON*	Fishing
10/18/2020	Big Island	9336	N20° 15.923'	W155° 54.891'	S11	*RIDE ON*	Fishing
10/18/2020	Big Island	9032	N20° 14.044'	W155° 55.789'	S13	*RIDE ON*	Fishing
10/18/2020	Big Island	8963	N20° 13.492'	W155° 55.226'	S10	*RIDE ON*	Fishing
10/18/2020	Big Island	8891	N20° 12.961'	W155° 55.810'	S10	*RIDE ON*	Fishing
10/18/2020	Big Island	8993	N20° 13.788'	W155° 56.655'	S22	*RIDE ON*	Fishing
10/23/2020	Big Island	8976	N20° 13.252'	W155° 42.036'	S10	*RIDE ON*	Fishing
10/23/2020	Big Island	9014	N20° 13.512'	W155° 41.457'	S15	*RIDE ON*	Fishing
10/23/2020	Big Island	9086	N20° 14.086'	W155° 43.166'	S10	*RIDE ON*	Fishing
10/23/2020	Big Island	9126	N20° 14.356'	W155° 43.160'	S10	*RIDE ON*	Fishing
10/23/2020	Big Island	9436	N20° 15.959'	W155° 41.979'	S20	*RIDE ON*	Fishing
10/23/2020	Big Island	9741	N20° 17.328'	W155° 42.810'	S22	*RIDE ON*	Fishing
10/23/2020	Big Island	9678	N20° 17.074'	W155° 43.677'	S22	*RIDE ON*	Fishing
10/23/2020	Big Island	9737	N20° 17.350'	W155° 43.958'	S22	*RIDE ON*	Fishing
10/23/2020	Big Island	9792	N20° 17.642'	W155° 45.100'	S20	*RIDE ON*	Fishing
10/23/2020	Big Island	9307	N20° 15.476'	W155° 45.145'	S10	*RIDE ON*	Fishing
10/23/2020	Big Island	9544	N20° 16.591'	W155° 46.843'	S05	*RIDE ON*	Fishing
10/23/2020	Big Island	9841	N20° 17.965'	W155° 47.963'	S20	*RIDE ON*	Fishing
10/30/2020	Big Island	7725	N20° 7.331'	W155° 29.835'	S10	*RIDE ON*	Fishing
10/30/2020	Big Island	8111	N20° 8.684'	W155° 29.805'	S20	*RIDE ON*	Fishing
10/30/2020	Big Island	8613	N20° 10.578'	W155° 29.763'	S24	*RIDE ON*	Fishing
10/30/2020	Big Island	8532	N20° 10.353'	W155° 32.062'	S23	*RIDE ON*	Fishing
10/30/2020	Big Island	8102	N20° 8.735'	W155° 32.384'	S17	*RIDE ON*	Fishing

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10/30/2020	Big Island	7871	N20° 7.934'	W155° 32.975'	S10	*RIDE ON*	Fishing
10/30/2020	Big Island	8094	N20° 8.780'	W155° 34.676'	S14	*RIDE ON*	Fishing
10/30/2020	Big Island	8240	N20° 9.338'	W155° 35.524'	S20	*RIDE ON*	Fishing
c10/30/2020	Big Island	8088	N20° 8.813'	W155° 36.396'	S10	*RIDE ON*	Fishing
10/30/2020	Big Island	8444	N20° 10.177'	W155° 36.939'	S20	*RIDE ON*	Fishing
10/30/2020	Big Island	8369	N20° 9.934'	W155° 38.378'	S10	*RIDE ON*	Fishing
11/15/2020	Big Island	8508	N20° 10.486'	W155° 38.940'	S10	*RIDE ON*	Fishing
11/15/2020	Big Island	8768	N20° 11.563'	W155° 38.630'	S20	*RIDE ON*	Fishing
11/15/2020	Big Island	8652	N20° 11.038'	W155° 39.502'	S10	*RIDE ON*	Fishing
11/15/2020	Big Island	8651	N20° 11.044'	W155° 39.788'	S10	*RIDE ON*	Fishing
11/15/2020	Big Island	8715	N20° 11.320'	W155° 40.069'	S10	*RIDE ON*	Fishing
11/15/2020	Big Island	8797	N20° 11.878'	W155° 40.918'	S10	*RIDE ON*	Fishing
11/15/2020	Big Island	8795	N20° 11.888'	W155° 41.491'	S02	*RIDE ON*	Fishing
11/15/2020	Big Island	8871	N20° 12.424'	W155° 41.193'	S10	*RIDE ON*	Fishing
11/15/2020	Big Island	9718	N20° 17.450'	W155° 49.408'	S05	*RIDE ON*	Fishing
11/15/2020	Big Island	9714	N20° 17.471'	W155° 50.556'	S07	*RIDE ON*	Fishing
11/15/2020	Big Island	9653	N20° 17.205'	W155° 50.848'	S10	*RIDE ON*	Fishing
8/22/2020	Oahu	34115	N21° 16.162'	W157° 53.898'	S22	*RENEE NV*	Fishing
8/22/2020	Oahu	34111	N21° 16.169'	W157° 55.054'	S24	*RENEE NV*	Fishing
8/22/2020	Oahu	33353	N21° 14.843'	W157° 59.690'	S23	*RENEE NV*	Fishing
8/22/2020	Oahu	35907	N21° 21.943'	W158° 9.479'	S22	*RENEE NV*	Fishing
9/3/2020	Maui Nui	24918	N21° 1.194'	W157° 14.466'	S24	*RENEE NV*	Fishing
9/3/2020	Maui Nui	24909	N21° 1.221'	W157° 17.063'	S17	*RENEE NV*	Fishing
9/3/2020	Maui Nui	23816	N21° 0.149'	W157° 18.230'	S16	*RENEE NV*	Fishing
9/3/2020	Maui Nui	24344	N21° 0.705'	W157° 19.667'	S20	*RENEE NV*	Fishing
9/3/2020	Maui Nui	24075	N21° 0.434'	W157° 19.670'	S20	*RENEE NV*	Fishing
9/3/2020	Maui Nui	22780	N20° 59.102'	W157° 21.993'	S22	*RENEE NV*	Fishing
9/13/2020	Maui Nui	24820	N21° 1.448'	W157° 42.749'	S20	*RENEE NV*	Fishing
9/13/2020	Maui Nui	23468	N21° 0.097'	W157° 43.338'	S14	*RENEE NV*	Fishing
9/13/2020	Maui Nui	20406	N20° 56.589'	W157° 45.387'	S14	*RENEE NV*	Fishing
9/13/2020	Maui Nui	20659	N20° 56.732'	W157° 29.519'	S24	*RENEE NV*	Fishing
9/16/2020	Maui Nui	24927	N21° 1.117'	W157° 7.253'	S22	*RENEE NV*	Fishing
9/16/2020	Maui Nui	25213	N21° 1.385'	W157° 6.961'	S22	*RENEE NV*	Fishing
9/16/2020	Maui Nui	25502	N21° 1.653'	W157° 6.669'	S22	*RENEE NV*	Fishing
9/16/2020	Maui Nui	26092	N21° 2.195'	W157° 6.662'	S22	*RENEE NV*	Fishing
9/16/2020	Maui Nui	26089	N21° 2.204'	W157° 7.528'	S22	*RENEE NV*	Fishing
9/16/2020	Maui Nui	26394	N21° 2.478'	W157° 7.813'	S15	*RENEE NV*	Fishing
9/16/2020	Maui Nui	26697	N21° 2.759'	W157° 8.675'	S22	*RENEE NV*	Fishing
9/30/2020	Maui Nui	32703	N21° 12.978'	W157° 1.902'	S07	*RENEE NV*	Fishing
9/30/2020	Maui Nui	32868	N21° 13.253'	W157° 2.187'	S10	*RENEE NV*	Fishing
9/30/2020	Maui Nui	33021	N21° 13.563'	W157° 5.651'	S05	*RENEE NV*	Fishing
9/30/2020	Maui Nui	33180	N21° 13.834'	W157° 5.647'	S10	*RENEE NV*	Fishing
9/30/2020	Maui Nui	33178	N21° 13.841'	W157° 6.225'	S05	*RENEE NV*	Fishing
9/30/2020	Maui Nui	33447	N21° 14.383'	W157° 6.218'	S20	*RENEE NV*	Fishing
9/30/2020	Maui Nui	33591	N21° 14.676'	W157° 8.238'	S05	*RENEE NV*	Fishing
9/30/2020	Maui Nui	34215	N21° 15.791'	W157° 11.114'	S20	*RENEE NV*	Fishing

Appendix B: Fall 2020 Camera Deployment Locations (Two per PSU) by Stratum, and Vessel

SAMPLE_DATE	Island	PSU	lat_deg	lon_deg	STRATA_2020	VESSEL	GEAR
10/08/2020	Oahu	37489	N21° 33.729	W157° 48.275	S10	*Ao Shibi IV*	Camera
10/08/2020	Oahu	37489	N21° 33.784	W157° 48.340	S10	*Ao Shibi IV*	Camera
10/08/2020	Oahu	37342	N21° 32.741	W157° 47.769	S10	*Ao Shibi IV*	Camera
10/08/2020	Oahu	37342	N21° 32.675	W157° 47.693	S10	*Ao Shibi IV*	Camera
10/08/2020	Oahu	36953	N21° 29.434	W157° 45.702	S11	*Ao Shibi IV*	Camera
10/08/2020	Oahu	36953	N21° 29.362	W157° 45.653	S11	*Ao Shibi IV*	Camera
10/08/2020	Oahu	36918	N21° 29.124	W157° 43.461	S03	*Ao Shibi IV*	Camera
10/08/2020	Oahu	36918	N21° 29.092	W157° 43.360	S03	*Ao Shibi IV*	Camera
10/08/2020	Oahu	36666	N21° 27.475	W157° 41.973	S10	*Ao Shibi IV*	Camera
10/08/2020	Oahu	36666	N21° 27.421	W157° 41.946	S10	*Ao Shibi IV*	Camera
10/08/2020	Oahu	36567	N21° 26.652	W157° 42.224	S10	*Ao Shibi IV*	Camera
10/08/2020	Oahu	36567	N21° 26.612	W157° 42.227	S10	*Ao Shibi IV*	Camera
10/08/2020	Oahu	36429	N21° 25.683	W157° 41.777	S10	*Ao Shibi IV*	Camera
10/08/2020	Oahu	36429	N21° 25.553	W157° 41.675	S10	*Ao Shibi IV*	Camera
10/08/2020	Oahu	36431	N21° 25.564	W157° 41.112	S03	*Ao Shibi IV*	Camera
10/08/2020	Oahu	36431	N21° 25.508	W157° 41.088	S03	*Ao Shibi IV*	Camera
10/08/2020	Oahu	36432	N21° 25.517	W157° 40.842	S10	*Ao Shibi IV*	Camera
10/08/2020	Oahu	34489	N21° 16.573	W157° 35.429	S02	*Ao Shibi IV*	Camera
10/08/2020	Oahu	34489	N21° 16.523	W157° 35.505	S02	*Ao Shibi IV*	Camera
10/08/2020	Oahu	34330	N21° 16.269	W157° 35.499	S02	*Ao Shibi IV*	Camera
10/08/2020	Oahu	35160	N21° 17.926	W157° 34.026	S02	*Ao Shibi IV*	Camera
10/09/2020	Oahu	33838	N21° 15.550	W157° 39.215	S04	*Ao Shibi IV*	Camera
10/09/2020	Oahu	34001	N21° 15.754	W157° 37.991	S04	*Ao Shibi IV*	Camera
10/09/2020	Oahu	34645	N21° 16.864	W157° 34.326	S06	*Ao Shibi IV*	Camera
10/09/2020	Oahu	34646	N21° 16.898	W157° 34.004	S06	*Ao Shibi IV*	Camera
10/09/2020	Oahu	35344	N21° 18.465	W157° 33.661	S12	*Ao Shibi IV*	Camera
10/09/2020	Oahu	33850	N21° 15.562	W157° 35.724	S09	*Ao Shibi IV*	Camera
10/09/2020	Oahu	34282	N21° 16.418	W157° 51.872	S16	*Ao Shibi IV*	Camera
10/10/2020	Oahu	40026	N21° 44.926	W157° 58.596	S08	*Ao Shibi IV*	Camera
10/10/2020	Oahu	40026	N21° 44.980	W157° 58.602	S08	*Ao Shibi IV*	Camera
10/10/2020	Oahu	40029	N21° 44.930	W157° 57.751	S09	*Ao Shibi IV*	Camera
10/10/2020	Oahu	40029	N21° 45.044	W157° 57.645	S09	*Ao Shibi IV*	Camera
10/10/2020	Oahu	40018	N21° 44.916	W158° 00.923	S09	*Ao Shibi IV*	Camera
10/10/2020	Oahu	40018	N21° 44.991	W158° 00.981	S09	*Ao Shibi IV*	Camera
10/10/2020	Oahu	39513	N21° 42.796	W158° 03.256	S01	*Ao Shibi IV*	Camera
10/10/2020	Oahu	39513	N21° 42.829	W158° 03.332	S01	*Ao Shibi IV*	Camera
10/10/2020	Oahu	39450	N21° 42.516	W158° 04.997	S11	*Ao Shibi IV*	Camera
10/10/2020	Oahu	39449	N21° 42.506	W158° 05.219	S10	*Ao Shibi IV*	Camera
10/10/2020	Oahu	38165	N21° 38.264	W158° 09.067	S16	*Ao Shibi IV*	Camera
10/10/2020	Oahu	38165	N21° 38.213	W158° 09.050	S16	*Ao Shibi IV*	Camera
10/10/2020	Oahu	38795	N21° 38.995	W158° 07.694	S14	*Ao Shibi IV*	Camera
10/10/2020	Oahu	38795	N21° 39.024	W158° 07.724	S14	*Ao Shibi IV*	Camera
10/10/2020	Oahu	38796	N21° 38.974	W158° 07.347	S05	*Ao Shibi IV*	Camera
10/10/2020	Oahu	38796	N21° 38.994	W158° 07.461	S05	*Ao Shibi IV*	Camera
10/11/2020	Oahu	38103	N21° 36.625	W158° 16.365	S01	*Ao Shibi IV*	Camera
10/11/2020	Oahu	38103	N21° 36.671	W158° 16.412	S01	*Ao Shibi IV*	Camera
10/11/2020	Oahu	38182	N21° 36.887	W158° 16.649	S05	*Ao Shibi IV*	Camera
10/11/2020	Oahu	38182	N21° 36.901	W158° 16.693	S05	*Ao Shibi IV*	Camera
10/11/2020	Oahu	38252	N21° 37.178	W158° 19.848	S07	*Ao Shibi IV*	Camera
10/11/2020	Oahu	38252	N21° 37.212	W158° 19.931	S07	*Ao Shibi IV*	Camera
10/11/2020	Oahu	38089	N21° 36.666	W158° 20.390	S08	*Ao Shibi IV*	Camera
10/11/2020	Oahu	38089	N21° 36.696	W158° 20.514	S08	*Ao Shibi IV*	Camera
10/11/2020	Oahu	37925	N21° 36.100	W158° 21.606	S16	*Ao Shibi IV*	Camera
10/11/2020	Oahu	37925	N21° 36.131	W158° 21.682	S16	*Ao Shibi IV*	Camera
10/11/2020	Oahu	35823	N21° 21.393	W158° 08.935	S15	*Ao Shibi IV*	Camera
10/11/2020	Oahu	35823	N21° 21.444	W158° 08.997	S15	*Ao Shibi IV*	Camera
10/11/2020	Oahu	35713	N21° 20.632	W158° 08.909	S03	*Ao Shibi IV*	Camera
10/11/2020	Oahu	35713	N21° 20.646	W158° 08.964	S03	*Ao Shibi IV*	Camera
10/11/2020	Oahu	34573	N21° 17.040	W158° 00.556	S01	*Ao Shibi IV*	Camera
10/11/2020	Oahu	34573	N21° 17.081	W158° 00.569	S01	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	26279	N21° 02.768	W157° 41.537	S02	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	26279	N21° 02.738	W157° 41.552	S02	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	29356	N21° 05.770	W157° 37.479	S02	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	29356	N21° 05.774	W157° 37.429	S02	*Ao Shibi IV*	Camera

SAMPLE_DATE	Island	PSU	lat_deg	lon_deg	STRATA_2020	VESSEL	GEAR
10/12/2020	Maui Nui	30747	N21° 08.617	W157° 29.450	S05	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	30747	N21° 08.684	W157° 29.385	S05	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	30673	N21° 08.345	W157° 26.271	S05	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	30673	N21° 08.395	W157° 26.234	S05	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	21526	N20° 57.868	W157° 29.268	S10	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	21526	N20° 57.851	W157° 29.373	S10	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	22517	N20° 58.881	W157° 26.572	S10	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	22517	N20° 58.921	W157° 26.631	S10	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	22765	N20° 59.146	W157° 26.275	S10	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	22765	N20° 59.188	W157° 26.271	S10	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	23017	N20° 59.418	W157° 26.019	S10	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	23017	N20° 59.480	W157° 26.009	S10	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	25752	N21° 02.071	W157° 21.732	S04	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	25752	N21° 02.137	W157° 21.718	S04	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	25772	N21° 02.076	W157° 16.034	S05	*Ao Shibi IV*	Camera
10/12/2020	Maui Nui	25772	N21° 02.153	W157° 16.056	S05	*Ao Shibi IV*	Camera
10/13/2020	Maui Nui	25772	N21° 02.047	W157° 15.876	S05	*Ao Shibi IV*	Camera
10/13/2020	Maui Nui	25772	N21° 02.104	W157° 15.888	S05	*Ao Shibi IV*	Camera
10/13/2020	Maui Nui	32337	N21° 12.642	W157° 18.111	S05	*Ao Shibi IV*	Camera
10/13/2020	Maui Nui	32337	N21° 12.630	W157° 18.056	S05	*Ao Shibi IV*	Camera
10/13/2020	Maui Nui	34030	N21° 15.592	W157° 18.076	S05	*Ao Shibi IV*	Camera
10/13/2020	Maui Nui	34030	N21° 15.670	W157° 18.108	S05	*Ao Shibi IV*	Camera